Sewage Works Journal

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Sewage Works

SEWAGE TREATMENT AT TORONTO*

By William Storrie

Consulting Engineer, Gore and Storrie, Toronto, Can.

Toronto, a name of Indian origin denoting "a place of meeting," is situated on the north shore of Lake Ontario, about 40 miles from its western end. It began as a village at the mouth of the small River Don, where a sand bar now called Toronto Island enclosed a natural bay. From a land area of less than 9 sq. mi. and a population of 9,254 persons in 1834, the city in 1946 has grown to a land area of 34 sq. mi. and a population of 696,555 persons. In addition to this urban population there are some 200,000 persons within the Toronto and Suburban Area, but residing outside of the city limits, most of whom secure water from the city's system.

The enclosed portion of Toronto Bay is roughly 2 miles long by 1 mile wide. It is almost completely land-locked, with dredged entrances some 400 ft. wide at the northwestern and southeastern corners. The central portion of the basin is 20 to 30 ft. in depth. Except where deepened by dredging, the water along the mainland shore is shallow, reaching a depth of 16 ft. at a distance of ¼ mile, more or less.

East of the turning basin and south of the mainland, there is a rather extensive area of shallow water and marsh, known as Ashbridge's Bay. It is about 1 mile long and ½ mile wide at the widest part. It formerly extended westerly nearly to the harbor, but much of the area has been reclaimed for industrial and harbor developments.

The existing Eastern Avenue sewage treatment plant is situated on the north shore of Ashbridge's Bay and at the present time there is under construction a sewage treatment plant for the city on the southern shore of the bay and fronting on Lake Ontario.

The city now extends 10 miles along the shore of Lake Ontario, from the Humber River on the west to Victoria Park on the east. The North Toronto district extends for a distance of about 8 miles as measured from the existing water purification plants at Toronto Island.

The central part of the city slopes gently upwards from Lake Ontario to a height of 200 feet. North of the city limits is a somewhat higher upland area, the highest point being 380 ft. above lake level, which is 245 ft. above the sea, a total elevation of 625 ft. above sea level.

The comparatively level surface of this area is broken by the deep valleys of the Don and Humber Rivers and their tributaries, which have been cut almost to lake level for a mile or two from shore and spread out as steep-walled ravines for several miles inland. Five streams furnish the natural drainage for the area in and around Toronto, namely, Highland Creek, Don River, Humber River, Mimico Creek and Etobicoke Creek.

* Presented at 19th Annual Meeting, Federation of Sewage Works Assns., Toronto, Can., October 7–9, 1946.

Water Supply

The water supply for Toronto is taken from Lake Ontario through three intake pipes. These consist of two submerged intakes situated about 2,190 ft. and 2,383 ft. off Centre Island in about 43 and 79 ft. of water, respectively. The water is pumped from suction wells to two water purification plants. The third intake is situated at the easterly limits of the city at Victoria Park and is placed in 50 ft. depth of water at a point about 7,200 ft. from the shore.

All along the water front and in the lagoons and lake shore at Toronto Island there are extensive bathing beaches.

The natural drainage, including the sewage from the entire area, flows directly or indirectly towards Lake Ontario. From the point of view of the Toronto sources of water supply and water supplies of other municipalities in the suburban area with Lake Ontario as the source, it was necessary to consider the problem of sewage disposal in a broad way and to ascertain how the interests of all may be best served.

Due largely to pasteurization of the milk supply and the filtration and chlorination of the water supply, the typhoid mortality rate has been reduced from 43 per 100,000 persons in 1910 to single deaths in 1941 and 1943 and none in 1942, 1944 or 1945. The typhoid mortality rate reached its highest peak in 1890 with 93.1 per 100,000 persons. Chlorination of the water supply commenced in 1910, the first municipality in Canada to adopt same.

Provincial Acts

The Public Health Act of the Province of Ontario, Section 94, states that "No sewage, drainage, . . . which . . . impair the quality of the water of any source of public water supply for domestic use . . . shall be placed in or discharged into the waters . . . of any such sources of water supply. . . ."

Section 95 of the Public Health Act requires the submission of plans for the construction or extension of a sewerage system to the Department of Public Health of Ontario for its approval. In this same section provision is made for the construction of a sewage treatment plant in an adjoining township, and for the purchase and employment of such lands as may be necessary for the purpose.

Pollution of Boundary Waters

The Final Report of the International Joint Commission relative to the pollution of boundary waters states: "The waters of the Greak Lakes constitute a class by themselves, and except at the points where the Detroit and Niagara Rivers enter Lake Erie and Lake Ontario, respectively, there is no pollution in them which crosses from one boundary line to the other, except it may be vessel pollution. . . . Outside of a margin along their shores and the polluted areas at the mouths of the rivers tributary to them, these waters are in their pristine purity with the exception of places where pollution from vessels exists."

It is clearly shown that shore pollution, as in the neighborhood of Toronto, does not affect the sanitary condition of the lake as a whole or of the boundary waters on the other side of the lake. However, this does not cover the responsibility of the city with respect to pollution of the boundary waters in all of its international aspects. The report further states: "Along the boundary waters, the citizens of both countries fraternize socially, select and patronize their summer resorts . . . almost without regard to territorial sovereignty. Such freedom of intercourse, however laudible, has the attendant danger of being conducive to the spread of disease and infection if either country fails to observe sanitary principles."

Toronto Main Sewage Works

Toronto in general is served by combined sewers. Such sewers receive both sewage and surface water runoff as contrasted with separate sewers and drains which receive sewage and surface water runoff, respectively, thus keeping them separate. Many of the sewers were built by outlying communities which were later absorbed by the city and when such districts were absorbed it was generally found that the sewers were quite inadequate and in some instances had to be scrapped. In many places storm overflow sewers discharge into the Don River, the lake, Toronto Bay and Ashbridge's Bay.

In 1908 the city engineer reported 3 to 4 ft. of sewage sludge covering the bottom of Toronto Bay. Annually about 20,000 cu. yd. of sludge deposits were removed from the bay slips.

The intercepting sewers were built between 1908 and 1912 and the Eastern Avenue sewage treatment plant was placed in operation in 1913. About 75 per cent of the sewage produced at present is collected and conveyed to the Eastern Avenue sewage treatment plant through two intercepting sewers. A high level intercepting sewer, varying in size from 3 ft. in diameter at its upper end to 9 ft. 6 in. in diameter at its lower end, has a total length of 9.3 miles. The low-lying area between the bay front and the high level sewer is served by a low level intercepting sewer, varying in size from 2 ft. 8 in. by 4 ft. at its upper end to 5 ft. 6 in. in diameter at the Eastern Avenue pumping station. This intercepting sewer is about 5 miles long.

Eastern Avenue Sewage Treatment Plant

The treatment at this plant consists simply of plain sedimentation. It was evidently intended by the designers to provide a sedimentation period of some 3 hours at an average flow of 33 m.g.d.* During recent years the flow has greatly increased with the result that the period of detention has been cut in half.

The sludge deposited in the sedimentation tanks is withdrawn at intervals of about 2 weeks and pumped into separate sludge digestion lagoons built in Ashbridge's Bay near the north shore. Digestion is encouraged by seeding with actively digesting sludge. It takes about 8 weeks to fill a lagoon with sludge, which is left for a period of 18 months to 2 years, during which digestion and consolidation take place. The sludge is then pumped by suction dredge to a land-locked area on the south side of Ashbridge's Bay, where it is used for filling and afterwards covered with sand.

The effluent from the tanks is discharged into the outlet conduit except that when the rate of flow is in excess of the capacity of this conduit the surplus escapes over a weir into a storm overflow channel and thence into Ashbridge's Bay.

The outlet conduit extends from the sedimentation tanks for a distance of 4,580 ft., terminating in a crib about ½ mile southeast of Coatsworth Cut and in water about 20 ft. in depth. The first 1,400 ft. of this 60-in. conduit consists of concrete pipe, beyond which it is constructed of flanged steel pipes.

The capacity of this outlet conduit varies with the elevation of the water in the lake. Under average conditions the total fall from the surface of the effluent at the tanks to the surface of the water in the lake is about 10 ft., and the capacity of the conduit under those conditions is about 65 m.g.d. or considerably less than the average rate of present dry weather sewage flow.

Sewage from a population of approximately 600,000 persons is conveyed to this plant.

* Throughout this paper, gallonage data refer to the Imperial gallon, which is equal to 1.2 U. S. gallons.

North Toronto Sewage Treatment Plant

The North Toronto sewage treatment plant serves that area of the city of Toronto known as North Toronto together with the suburban municipalities of the village of Forest Hill, the town of Leaside and a small portion of the township of York.

Until a few years ago the district served by the plant was almost wholly residential. In the past few years, however, there has been a great industrial growth in the town of Leaside, and as most of the employees in the factories there reside in other parts of the city and suburban areas the conditions have changed so that the actual population served by the sewage plant is considerably in excess of the resident population.

The sewage is conveyed to the plant through a system of sewers of the combined type carrying both storm water and sanitary sewage. The treatment plant of the activated sludge type consists of mechanically cleaned bar racks, hand cleaned grit channels, preliminary sedimentation tanks, aeration tanks, final sedimentation tanks, heated digestion tanks, glass-covered drying beds and a well equipped laboratory. There is also a sedimentation tank for treating storm flows in excess of twice the average dry weather flow.

The original plant was put in operation in 1929 and served a population of 50,000 persons with an average dry weather flow of 5 m.g.d. containing 167 p.p.m. of suspended solids. The enlarged plant as it now exists was placed in operation at the end of 1934 and was designed for a population of 100,000 persons and an average dry weather flow of 7.5 m.g.d. containing 200 p.p.m. of suspended solids and 200 p.p.m. of B.O.D.

The plant is now taking care of a population in excess of 100,000 persons with a dry weather flow of almost 9 m.g.d., while both suspended solids and B.O.D. are considerably higher than the designed capacity.

The bar screen at the entrance to the treatment plant has a clear bar spacing of 1 in. and is mechanically and automatically raked. The grit channels are four in number and manually cleaned. Each has a length of 45 ft. and a maximum water depth of 3 ft. 2 inches. The velocity is controlled to approximately 1 f.p.s. by proportional discharge weirs. There is a grit storage space 1 ft. in depth at the bottom of the channels.

The preliminary sedimentation tanks have a detention period of 2 hours at the rated average flow.

The aeration system consists of 8 spiral flow tanks with 10 ft. 6 in. depth of water, having a detention period of 4¾ hours at the rated average sewage flow plus 40 per cent of returned sludge.

The final settling tanks are 5 in number with a detention period of 4 hours and an overflow rate of 500 gal. per sq. ft. per day. Each final tank is equipped with two overflow troughs providing 240 ft. of overflow weir. The troughs are placed at right angles to the direction of the incoming sewage and at the quarter points of the tank. The amount of air used has varied from a maximum of 1.22 cu. ft. per gal. in 1938 to a minimum of 0.89 cu. ft. per gal. in 1945. This minimum rate is considered to be less than is essential for successful operation, as is shown by the B.O.D. results for 1945.

The mixed, raw and activated sludge is drawn from the preliminary settling tanks and pumped to the digestion tanks. There are 10 digestion tanks with a total capacity of 400,000 cu. ft. or 4 cu. ft. per capita on a designed basis.

The digestion tanks are heated by means of hot water coils operated at a maximum temperature of about 120° F., the heat being supplied from gas fired boilers.

The digester gas is burned under horizontal return tubular boilers and the steam generated is used for heating the plant, including the glass-covered sludge drying beds and digestion tanks. The gas is sufficient for all heating purposes except during extremely cold weather when it is supplemented by fuel oil. During the warm summer months part of the gas is burned to waste. The heat value of the gas is around 600 B.t.u. per cubic foot.

The digested sludge is dried on glass-covered sand beds. The dried sludge is removed from the beds by hand and transported to the dump in cars operated on industrial railway tracks. To facilitate drying it has been found necessary to add powdered alum to the sludge as it is applied to the beds. The addition of alum at the rate of about 8 per cent of the dried solids in the digested sludge permits of a drying rate of about 4 lb. of dried solids per square foot of sand bed per month. The dried sludge contains about 82 per cent moisture.

When the initial installation of this plant was constructed vacuum filtration had not been developed to such an extent as to warrant its use.

Operating Results

Infrequent records of the bacteria reduction by the plant have been made and continuous records over a 3-month period in 1935 showed a reduction of 99.4 per cent in bacteria and 99.0 per cent in *B. Coli.*

The operating results of the North Toronto plant have been most satisfactory and compare favorably with those of any other sewage treatment plant. Although suspended solids and B.O.D. loadings have considerably increased over the designed basis the plant shows a high reduction in both suspended solids and B.O.D. With the plant now overloaded both as to volume of sewage, suspended solids and B.O.D., together with a reduction in the amount of air used per gallon, the efficiencies have been reduced somewhat. The population served is undoubtedly much higher than the number of persons resident in the area discloses, due to the large number of industrial workers in a portion of the area who live outside of the sewer systems connected to the North Toronto plant.

It is not anticipated that any further extensions will be made to this plant, as the effluent discharges into the Don River where in summer the river flow is only twice that of the volume of sewage being discharged into it. The most likely addition or changes in operating methods will be the installation of vacuum filters to take the place of the glass-covered sludge drying beds.

The North Toronto plant was designed with a view to affording as great a protection to the purity of the Don River as is practicable. It has demonstrated the practicability of the activated sludge process employed, and has been used for test purposes in connection with a large number of special problems, the results from which are being incorporated in the new sewage treatment plant for the city as a whole now under construction at Ashbridge's Bay.

The North Toronto plant was a pioneer among such plants with respect to:

1. The use of preliminary sedimentation in conjunction with the activated sludge process.
2. The digestion of preliminary and excess activated sludge solids in heated gas-tight tanks.
3. The drying of such sludge upon glass-covered beds.

The plant has demonstrated the soundness of the plan originally adopted for the treatment of the sewage at North Toronto.

A general summary of the operating results for the last 10-year period is shown in Tables 1 and 2.

TABLE 1.—Ten-Year Operation Summary, North Toronto Sewage Treatment Plant *

Year	Raw Sewage			Aeration		Per Cent Removal	
	Flow (m.g.d.)	Pounds Suspended Solids Daily	Pounds B.O.D. Daily	Per Cent Return Sludge	Hours Detention	Suspended Solids	B.O.D.
1936	5.44	13,020	13,570	23	7.5	96.6	94.3
1937	6.00	13,080	14,600	21	6.9	95.9	93.0
1938	5.60	14,670	14,280	19	7.5	96.6	94.1
1939	6.03	16,760	15,260	23	7.0	96.8	94.0
1940	6.43	18,000	18,650	30	6.0	97.5	94.8
1941	6.99	21,670	19,570	18	6.1	96.5	95.0
1942	7.28	24,750	20,380	19	5.8	95.0	94.3
1943	7.92	22,940	18,980	20	5.3	94.1	91.7
1944	7.35	20,550	19,080	26	5.4	93.2	88.5
1945	8.65	22,500	20.650	22	4.75	90.3	82.5

* Note following increases in the decade: population—31%; sewage flow—72%; suspended solids—89%; B.O.D.—76%.

Ashbridge's Bay Sewage Treatment Plant

In 1933 a report was submitted recommending that a sewage treatment plant for the city as a whole be constructed at Highland Creek, a distance of about 10 miles east of the easterly city boundary. This site was selected well outside of the city limits after instructions had been issued by the Council "That the proposed new sewage treatment plant shall not be located on Eastern Avenue at the site of the existing Main Sewage Disposal Works, and further that the Eastern Avenue plant be eliminated." The estimated cost of the proposed works amounted to $20,428,000 but the project had to be abandoned, due primarily to the large expenditure involved in carrying an outfall sewer from the existing Eastern Avenue pumping station to the Highland Creek site, at an estimated cost of $9,374,000.

A supplementary report was submitted in 1935, which recommended that the sewage treatment plant be constructed on the shores of Lake Ontario immediately south of the existing Eastern Avenue plant. This plant is now under construction and it is the purpose of this paper to deal with some of the features connected with the scheme.

An exhaustive investigation was made of the characteristics of the Toronto sewage and, in an effort to arrive at reasonably definite conclusions regarding same, the wastes from all the large industries were analyzed.

Little difference was found in the average composition of the sewage from the high level interceptor, which is largely of domestic origin, compared with that coming from the low level interceptor, which contains

TABLE 2.—Ten-Year Record of Population, Air Used and Gas Production, North Toronto Sewage Treatment Plant

Year	Resident Population Served	Air Cubic Feet Per Gallon	Gas Produced Per Day	
			Cubic Feet	Cubic Feet Per Capita
1936	75,670	1.15	112,600	1.49
1937	79,900	1.16	109,500	1.37
1938	82,177	1.22	127,000	1.55
1939	86,122	1.17	127,000	1.48
1940	88,745	1.10	131,000	1.48
1941	92,121	1.05	147,000	1.60
1942	94,931	0.90	141,500	1.49
1943	96,729	0.99	134,700	1.39
1944	98,561	1.04	147,500	1.50
1945	100,324	0.89	148,800	1.48

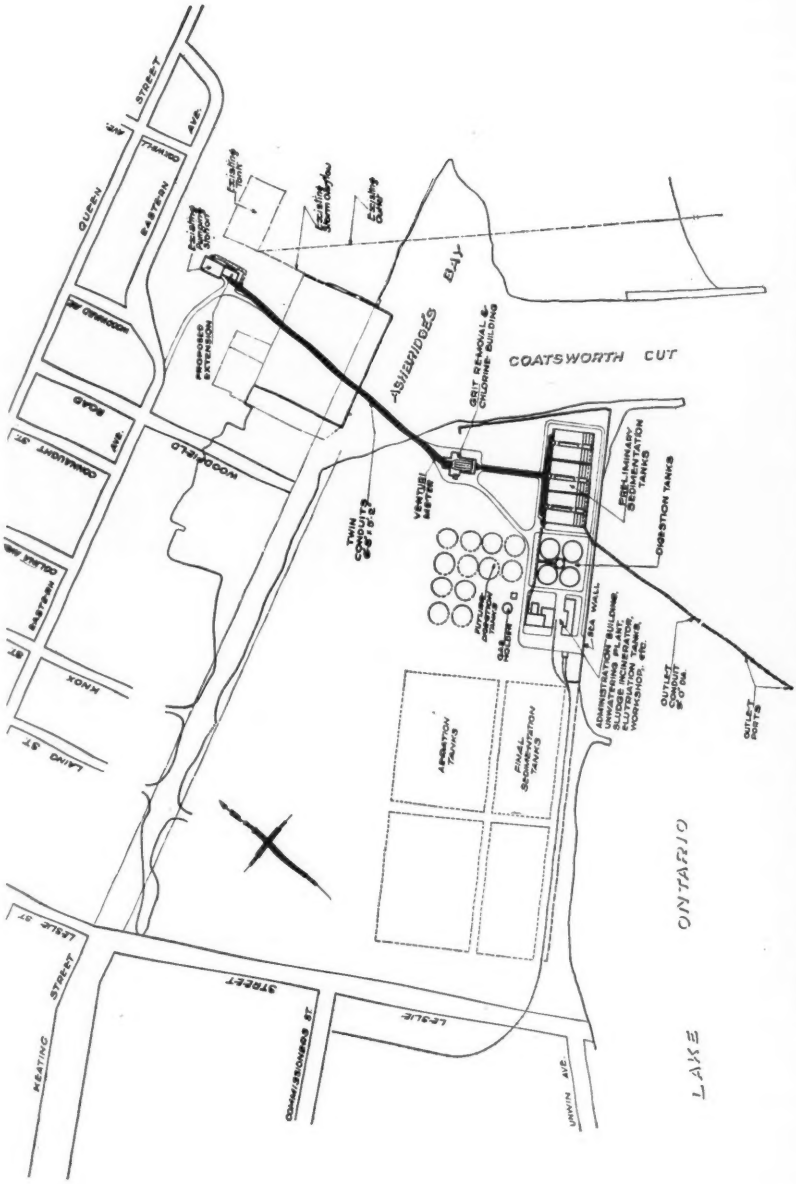

FIGURE 1.—General layout of Ashbridge's Bay sewage treatment plant, Toronto, Can.

substantial quantities of industrial wastes. The only wastes present which might require control because of their unfavorable effect upon the treatment process appear to be those carrying oil or tar. The high level sewage varies markedly in strength during the 24 hours, being much stronger during the day than at night. It was found, however, that the sewage to be delivered to the new treatment plant will vary less in strength and volume because of the equalizing effect of the pumping and of the long period of flow in the intercepting sewers.

As a result of this investigation it is estimated that the sewage delivered to the new treatment plant will have the following composition:

	P.P.M.
Suspended solids	275
5-Day B.O.D.	275
Oxygen consumed	120
Ammonia nitrogen	16
Albuminoid nitrogen	8

Although this estimate agrees moderately well with the average composition of the North Toronto sewage, the quantities of sewage matter per capita of tributary population are much greater for the city-at-large. The excess is due to two influences, the industrial wastes and the transient population, both of which are much greater in the city than in North Toronto.

Compared with the strength of the sewage in large cities in the United States the allowances for Toronto are slightly above the average.

Degree of Treatment Required

A great deal of controversy arose as to whether partial or complete treatment of the sewage was necessary. The consulting engineers for the city, Metcalf & Eddy and Gore & Storrie, emphatically stated that complete treatment of the sewage was essential. This opinion was confirmed by four out of five members of the Board of Review engaged to study the situation, the Commissioner of Works, the Medical Officer of Health and the Ontario Department of Health.

Due to the outbreak of the war the construction work was delayed. Conditions became so bad, however, that it was decided to proceed with the work, although the then prevailing conditions as to labor and materials were far from favorable.

The Ontario Department of Health decided to permit the city to proceed with the work in two stages leading towards complete treatment. This was agreed to on the distinct understanding that work on the second stage covering complete treatment would be undertaken within 4 years of the operation date of the first stage.

Construction Work

Only two contracts have so far been placed under construction. The first contract covers the sea wall, sedimentation tanks and digestion tanks, and the work is about 70 per cent completed. The second contract for the 9-ft. diameter outlet conduit is well under way and a start has been made in laying the conduit, commencing at the pipe laid as part of the sea wall.

The foundations of the sea wall, sedimentation tanks and digestion tanks were everywhere well below lake level. This necessitated the lowering of the ground water by a system of well points so as to enable all concrete foundations to be placed in the dry.

The site was such that it had to be protected by a sea wall and, like all the other structures, supporting piles of timber had to be driven. Such piles averaged about 32 ft. in length of not less than 7 inches in diameter at the small end, and 12 inches in diameter at the butt end. Each pile was driven so as to have a bearing value of at least 20 tons. In all over 50 miles of timber piles have been driven for supporting the structures.

The steel reinforcing, Portland cement, sand and gravel used in the work complied with the recognized standard

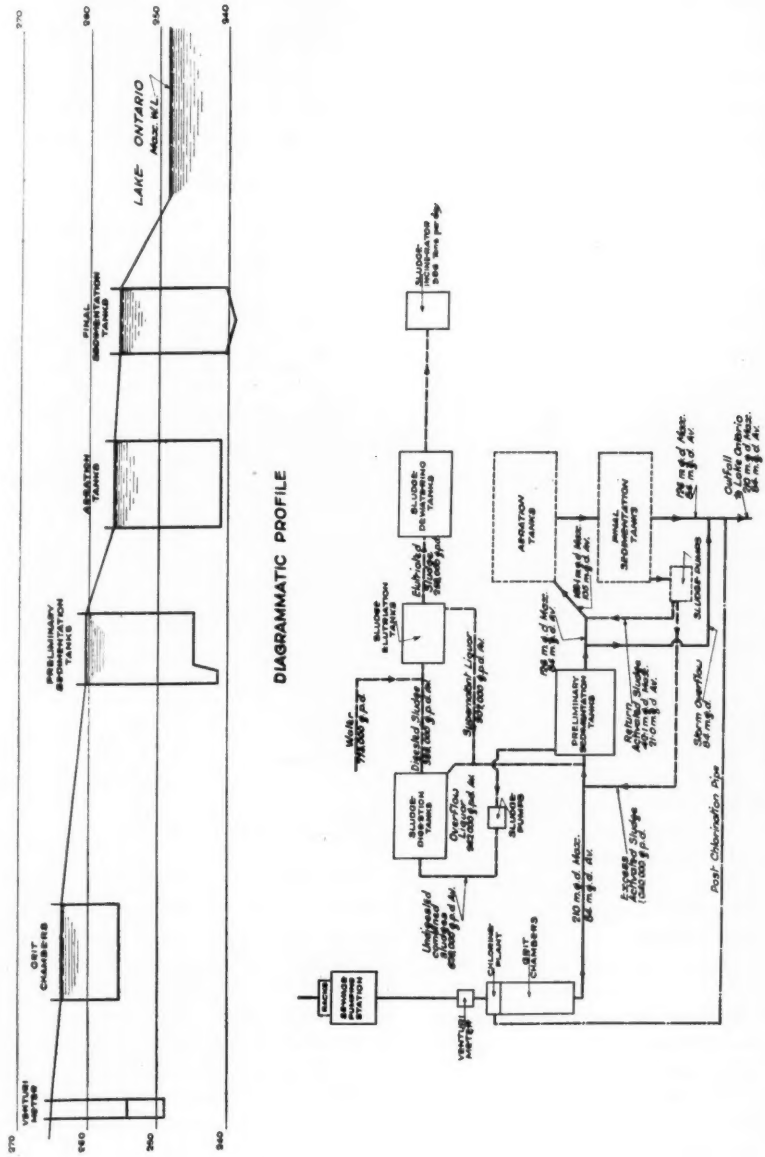

FIGURE 2.—Flow diagram of Ashbridge's Bay sewage treatment plant, Toronto, Can.

specifications. Three classes of concrete were used with minimum compressive strengths at 28 days of 3,000, 2,000 and 1,500 p.s.i., respectively.

Sea Wall

The throw-back type sea wall protecting the site has a total length of 1,385 feet. It has a base of 14 ft. carried on pile bents at 4-ft. centers and protected on the lake face by 4-in. wood sheet piling securely anchored to the concrete wall by 1-in. anchor bolts at 3-ft. centers, through an 8-in. by 10-in. timber running along the entire length of the wall. The bottom of the wall base is at Elevation 240.0, the high water level is Elevation 249.2 and the top of the wall, which is 3 ft. wide is at Elevation 255.0. The 4-in. sheet piling is carried from the top of the concrete base at Elevation 242.0 to Elevation 228.0.

Sedimentation Tanks

There are six sedimentation tanks each 200 ft. long, 66 ft. 6 in. wide with an average water depth of 14 ft. 8 in. below the effluent weirs. The tanks are covered with a concrete roof, and each tank is separated into four channels by longitudinal walls.

In each of the sedimentation tanks are placed four longitudinal sludge collector mechanisms of the drag scraper type, one cross sludge collector and one cross scum collector, each operated separately by an electric motor and speed reducer.

The sewage coming to the sedimentation tanks will pass through screens at the Eastern Avenue pumping station, such screens consisting of bar racks with 1-in. clear spacing. The rakings removed therefrom will be macerated and returned to the sewage ahead of the screens. At the treatment plant the sewage will pass through mechanically cleaned grit chambers at a velocity not exceeding 1 f.p.s. before passing into the sedimentation tanks. The grit will be washed and used as fill.

In the sedimentation tanks the longitudinal collectors will have a speed of about 2 f.p.m. and the cross collectors a speed of about 4 f.p.m.

The necessary sludge and scum pumps are of the centrifugal Scrupeller type, and electrically operated.

Digestion Tanks

There are four digestion tanks each 100 ft. in diameter, with cone shaped bottom and a concrete roof supported by 12 concrete columns. The tanks have a depth of 44 ft. 2 in. measured from the invert of the cone to the underside of the roof at the center of the tank, and a depth of 30 ft. 6 in. at the tank wall.

In designing the tanks the following data were used:

Weight of sludge	64 lb. per cu. ft.
Overflow weir	Elevation 277.0
Normal gas pressure	8 in. water
Maximum gas pressure	24 in. water
Snow load	40 lb. per sq. ft.
Roof live load	25 lb. per sq. ft.
Maximum lake level	Elevation 249.0
Minimum lake level	Elevation 243.0
Allowable load on piles	20 tons
Concrete	3,000 p.s.i. at 28 days
Reinforcing steel	Bending 20,000 p.s.i. Ring tension 16,000 p.s.i.
All reinforcing laps	42 diam.

Each digestion tank has a hot water heating system consisting of 3-in. diameter wrought iron pipe welded coils mounted on structural steel supports 2 ft. 6 in. from the tank wall and spaced at 22-in. centers. The plant heating system will operate with a water temperature of 180° F. but the water will be recirculated through the coils to maintain automatically any desired inlet temperature between 100° and 130° F. Each tank roof has 4 access manholes, 1 relief manhole, 3 sampling wells and a gas dome placed in the central part of the roof.

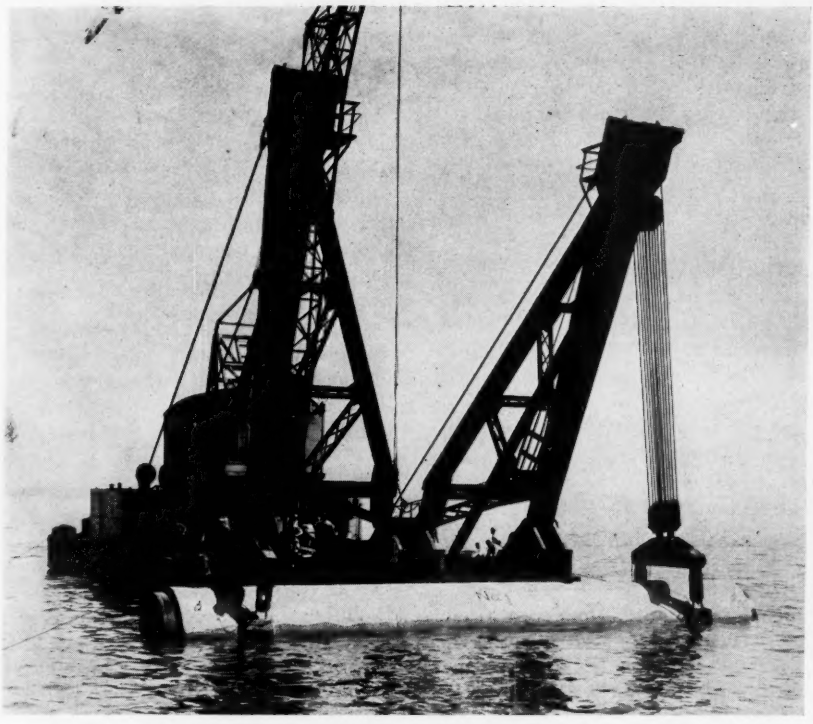

FIGURE 3.—Positioning the first section of the outlet line of the Ashbridge's Bay sewage treatment plant at Toronto.

An octagonal control building is placed in the central area between the four digestion tanks.

All gas piping will be laid underground from the tanks to a separate gas control building.

Outlet to Lake Ontario

The outlet conduit is 9 ft. inside diameter, constructed of reinforced concrete of a thickness of 9 inches. The outlet extends a distance of 3,300 ft. from the shore shaft; terminating in 27 ft. of water. The outlet conduit along its entire length is below the bed of the lake with access manholes spaced from 300 to 400 ft. apart. The outlet when laid has a minimum depth of 2 ft. of cover over the top of the conduit. The conduit is made up of one length 65 ft. long, 30 lengths each 100 ft. long, one length 86 ft. long and one length 82 ft. long. The outer 268 ft. decreases by stages from 9 ft. to 4 ft. in diameter, and along this length of conduit 8 outlet ports on top of the conduit are constructed each 4 ft. in diameter and extending a distance of 2 ft. above the lake bottom. The outer portion containing the outlet ports has a minimum cover of 4 ft. above the top of the conduit.

Each 100-ft. length of conduit weighs 250 tons. The outside of the conduit is horse-shoe shaped and the inside a true circle. There are two sets of lifting eyes for each length of conduit, spaced 24 ft. 6 in. from each end. Lifting eyes are formed by bending 1¾ in. square bars, the ends being embedded in the concrete in the lower half of the pipe.

The manholes consist of a cast iron frame, rubber gasket and cast iron cover. Each distributor consists of a cast iron frame set in the concrete, a section of cast iron pipe and a cast iron cover plate. All bolts and nuts are of chrome-nickel-iron containing approximately 18 per cent of chromium, 2 per cent of nickel and 0.2 per cent of carbon.

The trench has a width of not less than 12 ft. at the bottom with slopes sufficiently flat to prevent the sliding of material to the bottom of the trench. After the trench is excavated to the necessary depth, two special beds are prepared for each length of pipe by the depositing of gravel or clean sand on the bottom of the trench at the quarter points of the length and left slightly above grade to allow for settlement when the pipe is placed. After the pipe is placed in the proper position and joints made, all voids under the pipe are filled with gravel by means of water jetting. The bed is to be at least 3 ft. wider than the base of the pipe and prepared so as to have a uniform bearing for the conduit.

Contracts Still to be Awarded

From the foregoing it will be seen that a good start has been made on the construction of the new plant. Extreme difficulties have been encountered in getting the necessary materials and equipment and a scarcity of labor has added to the slow progress of the work.

Contracts are still to be awarded for pumping equipment, vacuum filters, incinerators, chlorinators and other incidental equipment, together with the necessary buildings to house same, as well as the outfall sewer to link up the existing sewage pumping station on Eastern Avenue with the new plant. Once this has been accomplished the first stage covering partial treatment will have been completed.

The second stage for complete treatment of the sewage calls for adding additional sedimentation and digestion tanks together with aeration and final sedimentation tanks.

EVALUATION OF METHODS OF HEATING SLUDGE*

By Henry J. Miles

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The application of heat to sludge before or during the digestion process is complicated by several factors peculiar to the material handled and the treatment to which it is subjected. In order to evaluate properly the various methods of supplying heat it is essential that these factors be considered and the limitations which they impose be recognized.

Factors Peculiar to Sludge Digestion

The heat requirements vary at different stages of the digestion process. A considerable amount of heat is required to raise the incoming sludge to the temperature of the digestion tank. As the digestion proceeds, it is essential that the temperature be maintained within a certain optimum range. As digestion nears completion, it is less important to maintain the sludge within this range.

The gas formed by the decomposition of sludge forms a highly explosive substance when mixed with the proper amount of air. While good design practice would practically eliminate the possibility of air entering a digester, it is always wise to be on the safe side and not use any type of heating equipment which would make possible the introduction into a digester of an open flame or a hot surface approaching ignition temperature.

The sludge contains millions of living organisms essential to the digestion process, and which can be destroyed by heat. It is therefore essential that no method of introducing heat into the sludge be used which would raise too great a proportion of the sludge to excessive temperatures for prolonged periods of time.

Basic Principles of Heat Exchange

In practically all methods in common use for heating sludge, the heat is supplied by conduction and convection. Some metal surface (heat exchanger) is usually heated directly or by a hot liquid and this surface transfers its heat to the adjacent sludge. The transfer of heat through the metal wall is by conduction and through the sludge by a combination of convection and conduction.

Between the metal surface and the main body of the sludge, however, is a thin film of sludge through which heat is transferred solely by conduction. Also on either or both sides of the metal wall there may be a scale which further inhibits the transfer of heat. It can therefore be seen that the transfer of heat from a metal wall to the sludge is a function of the conductivity of the metal wall; the conductivity of the scale, if present (known as scale coefficient); the conductivity of the intermediate film (known as film coefficient); and the conductivity of the sludge.* Finally, the quantity of heat required to raise the temperature of the sludge to a given level is a function of the specific heat of the sludge, which varies with the type, concentration, and degree of digestion. Any system of applying heat to sludge would have to be evaluated in the light of its effect on one or more of the various factors just mentioned, or the elimination of some of them.

The numerical values of the thermal conductivity of heat exchanger walls

* Presented at Nineteenth Annual Meeting, Federation of Sewage Works Assns., Toronto, Can., October 7–9, 1946.

* See appendix.

and scale coefficients for both hot and cold sides of heat exchangers have been determined and are available in various books on heat exchangers. Since the specific heat and conductivity of sludges, and film coefficients for the sludge side of heat exchangers are not nearly so readily available, however, some values will be presented here as a basis for future discussion.

Specific heat

The specific heat of sludge is usually taken as unity. Sierp (11), using the method of mixtures, concluded that the specific heat of sludge is practically the same as that of water.

Conductivity

Very little information is available on this subject. Keefer and Kratz (6) give the following values as determined for them on certain samples by the Bureau of Standards:

	Moisture (%)	Volatile Matter (%)	Thermal Conductivity (B.t.u./hr./sq. ft./deg. F./in.)
Raw sludge	87.4	70.8	4.5
Semi-digested sludge	87.4	65.1	5.1
Digested sludge	87.3	51.1	4.7
Water (for comparison)	—	—	4.1

Film Coefficient

A few scattered figures are available for the common hot water heating coils in digestion tanks. P. Langdon (8), reviewing the data from eight plants, states that values range from 10 to 20 B.t.u. per hr. per sq. ft. per deg. F. Queer (9) in laboratory studies using ¾-in. brass pipe obtained values ranging from 12 for heavy sludge to 88 for supernatant. The value for water in the same apparatus he determined as 116. Walraven (12) from field tests made in a digester with new clean heating coils obtained 11 to 12 for sludge with 12 per cent solids and 39 for strong supernatant. Young and Phillips (14) using a 2-in. wrought iron pipe coil and sludge between 5 and 12 per cent solids obtained 17.7. For heat exchangers outside the digester and using two concentric pipes, the inner carrying sludge and the outer hot water, P. Langdon (8) estimates values to be from 200 to 500 B.t.u. per hr. per sq. ft. per deg. F.

The author is at present engaged in making laboratory and field tests for securing further data on specific heats, conductivities, and film coefficients for both natural and forced convection.

As seen from the data presented, sludge has about the same specific heat as water, a slightly greater conductivity, and a very low film coefficient. Therefore the problem of heating sludge as compared to that of heating water resolves itself largely into methods of overcoming the sludge film coefficient bottleneck.

The methods used in modern sanitary engineering practice for heating sludge digestion tanks can be divided into two general classifications, namely, those which introduce heat directly into the digester and those which heat the sludge outside the digestion tank. Each of these types will be considered briefly and an attempt made to evaluate their suitability.

Heaters Within the Digester

Horizontal Hot Water Coils

This is by far the most common method in use, although newer methods are rapidly challenging its previous almost complete monopoly of the field. The heating coil is in the form of a spiral around the inside periphery of the tank. Hot water is admitted at the top of the coil and removed at the bottom. The coils should be placed in the most rapidly digesting sludge, which in single stage tanks is usually considered to be in the zone between a few feet above the bottom to slightly over mid-depth.

The main disadvantage of this method is the absolute dependence for

heat transfer on the natural convection currents induced in the sludge by the heating coils and the circulation caused by gas bubbles rising to the surface. In many digestion tanks, slow moving mixers are used, but these are primarily for the purpose of insuring more uniform gas production. As already mentioned, the film coefficient of heat transfer from the coils to the sludge is very low, about one-tenth that for water. Bacon (2) recommends placing the coils at least 3 ft. from the side walls to promote better convection currents.

When it is also realized that because of the tendency for a highly insulative scale to form on the outside of the coils unless the temperature of the heating water is kept below 130° F., thereby making a very small differential temperature between the inside and outside of the heating coil, the disadvantage of a low film coefficient is apparent.

Another important disadvantage of this method of heating is the difficulty of making repairs to the coils. As pointed out by L. Langdon (7), failure of a coil means that the digestion tank must be taken out of service for a considerable period of time, as it must be completely cleaned and ventilated before workmen can enter because of explosion hazards. As he further points out, in many plants with the digester out of service the entire plant must be by-passed as there is no other place to put the sludge. Failure of a coil has in some instances caused sludge to be drawn into the heating boiler or a gas engine where engine jacket water is circulated through the coils.

Vertical Hot Water Pipes

In an effort to correct some of the aforementioned difficulties, some plants have installed vertical heating pipes. As stated by Wittwer (13), this type of heater should be removable from the top. The vertical pipes are in series and are placed from 5 to 7 inches on centers. Hot water is introduced into the top of the first pipe and is circulated down and up through succeeding pipes until removed from the top of the last pipe. This type of heater is placed at or near the center of a small digester, and several are distributed uniformly about larger tanks. In some installations the vertical circulation of the sludge is aided by impellers rotating about a vertical axis.

The vertical pipes have the decided advantage of ease of removal of the entire heater or individual pipes for cleaning. Also there is less tendency for scum to adhere to the outside pipe wall, which in the case of horizontal coils sometimes results in failure of the pipe supports. Unless aided by artificial circulation it is questionable if the film coefficient of heat transfer is greater than that of horizontal coils.

Submerged Gas Burners

In a recent article, Keefer (5) describes two new types of heaters in which the heat of a gas flame is transmitted direct to the inside of a heat exchanger submerged in the digestion tank:

"The open type burner consists of a short length of pipe of any desired diameter, open at the discharge end. Near the open end is a perforated plate, through which the air-gas mixture flows. . . . The advantage of this type of burner is that the flame and the burnt gases make direct contact with the sludge, the result being that there is practically no heat loss. The closed type burner is designed so that the flame and products of combustion are contained within a closed container, constructed of pipe and immersed in the sludge."

Keefer claims that in a two months test of an open type heater no insulating crust was formed on the outside of the heater walls. No statement is made by him regarding the closed type heater, but it is assumed that it is expected to behave in the same way, otherwise it would have to be removed

at frequent intervals for cleaning. The closed type heater has the definite advantage over the usual hot water coil in that a much greater temperature differential across the walls of the heat exchanger can be used, thereby increasing the rate of heat transfer although the film coefficient remains the same. The open type heater has the additional advantage of increased circulation of the sludge past the outside of the heater due to the discharged gases, thereby increasing the film coefficient of heat transfer. Discussing the advisability of introducing burnt gases directly into the digester, thereby diluting the digester gas which is to be used as fuel, Keefer states that "designs have also been prepared which would provide for an open type burner in a covered digester and which would eliminate the possibility of burned gases mixing with the unburned gases." The writer invites discussion on the advisability of introducing an open flame into a digester, a procedure which radically differs from present safety practices.

"Radiant" Heating

A new method proposed by Wenzel (1) is that of applying "radiant" heating to digesters. Since exposed heating pipes are a source of so much trouble, he suggests burying the coils in the concrete floor and walls. Since the tank would be full of sludge, this would not really be a case of radiant heating but of conduction and convection, the heat exchanger being the tank itself. The film coefficient should be practically the same as that for the wrought iron heating coils, but in addition to the conductivity of the pipe walls, which is usually taken at about 370 B.t.u. per hr. per sq. ft. per deg. F. per inch thickness, there would be that of the concrete which is about 12 units. Thus, in effect, the added resistance of the concrete would inhibit the flow of heat.

Steam and Hot Water

Other methods for heating sludge in digestion tanks include the direct introduction of steam or hot water into the tanks. The use of steam, proposed by Rawn (10), will be discussed later under outside heat exchangers. Commenting on the use of hot-water, Wittwer (13) states that it is of German origin and up to the present time has not found much favor in this country. He mentions studies by Keefer (4), who found that more heat was required to heat the sludge by the direct addition of hot water than was the case with well designed heat exchangers using circulated water. The cost of the pipe heating coils is saved but water must be continually purchased and cannot be reused. He also mentions studies by Downes (3), who claims that the practice of introducing hot water directly into the sludge tends to segregate grit and coarse particles. The continual addition of hot water also takes up valuable space in the digester or adds to the volume of supernatant to be treated.

Heaters Outside the Digester

Addition of Steam to Raw Sludge

Rawn (10) and Bacon (2) have successfully used live steam to heat the daily additions of raw sludge to the digester, thereby maintaining the desired temperature in the tanks. The raw sludge is transferred from the sedimentation tanks to sludge concentration tanks, where it is mixed with 20 per cent by volume of digested sludge for "seed." The mixture is then transferred to the sludge digestion tank and, as the transfer pump starts, live steam is directed into the hopper bottom of the concentration tank from which the sludge mixture is drawn. The piping arrangement is such that preheating and recirculation to the concentration tanks is possible. As the digesters show a temperature drop of only 2 or 3° F., no further heating of

the sludge is necessary. The steam pressure is less than 15 p.s.i.

In answer to the question as to the quantity of steam condensate added to the sludge, Bacon (2) states "neglecting losses, this amounts to . . . 1 gallon per 10° F. temperature rise for every 110 gallons of sludge heated."

The advantage claimed by Rawn (10) for this method of heating sludge as compared to other types of heat exchangers outside the digestion tank is its flexibility, permitting the use as a heat exchanger, of any receptacle which will hold sludge, and making possible easy and quick adjustments for variation in the temperature of the incoming sludge, by regulating the flow of steam or the speed of the transfer pump. This method has the further advantage of eliminating entirely the sludge film coefficient of heat transfer bottleneck, that is encountered in all other methods already mentioned. The question of sterilization of the sludge by the live steam is answered by the successful use of the method for over six years. Apparently the number of bacteria killed by the steam is very small in proportion to the total number present.

Hot Water Heat Exchangers

L. Langdon (7) and P. Langdon (8) describe heat exchangers in which the sludge is circulated through pipes surrounded by hot water. The former type has the heating coils immersed in a hot water bath. A pump continuously circulates the sludge in the upper two thirds of the digester through the pipes in the heat exchanger. Provision is made for adding the raw sludge to the circulating material before it enters the heater. This arrangement is particularly recommended for smaller plants where sludge additions to the digester are intermittent and preheating the raw sludge on a batch basis would require excessive heating capacity which would operate intermittently and with considerable manual attention.

The latter type developed for the Hunts Point Plant in New York City consists of two concentric aluminum pipes, 6 and 8 inches in diameter. The raw sludge is pumped through the inner pipe and hot water circulated in the opposite direction through the annular space. It is estimated that under the most severe weather conditions the sludge will have to be heated to 97° F. in the exchangers in order to maintain a temperature of 85° F. in the digesters.

The choice of aluminum was based primarily on corrosion resisting properties. At maximum load the water passing through the heat exchanger will drop from 138° F. to 118° F. and the sludge will be raised from 50° to 108° F. It is expected that the temperature will be high enough to melt any grease which forms on the inside of the sludge pipes but low enough to avoid sludge caking.

One decided advantage of the forced circulation heat exchangers over the natural convection type is that the sludge film coefficient of heat transfer is increased. The only data available to the author is the estimate of P. Langdon (8) for the Hunts Point Plant of 200 to 500 B.t.u. per hr. per sq. ft. per deg. F.

Comparison of Sludge Heating Methods

It is apparent that external heat exchangers have a definite advantage over the internal heating coils in the amount of heat that can be transferred to the sludge per square foot of exchanger surface. This might counterbalance the objection raised to outside heat exchangers that the sludge must be raised to a higher temperature to overcome all the losses from the exchanger and digester.

One decided advantage of the external type of heater is its accessibility for cleaning and repair. Piping can

be arranged so that different exchangers can be used with the same digestion tank, thereby avoiding the necessity of taking a digester out of service when making repairs on the heater, as is the case when each digester is dependent entirely upon its own internal heating system. External heaters also make it possible, as pointed out by Rawn (10) to "control the sludge temperature in any receptacle which will hold sludge, whether it be an earthen pit, a lined retention chamber—covered or uncovered—an unused tank or basin, or a regulation sludge digestion unit."

Finally, as mentioned by L. Langdon (7) the external heat exchanger avoids the sudden temperature drops and accompanying decreased gas production noticed in some digesters when unheated raw solids are added.

Appendix

Mathematical relationship of heat transfer coefficients:

$$q = UA(T_i - T_0)$$

$$\frac{1}{U} = \frac{1}{h^1} + \frac{1}{h_d{}^1} + \frac{x}{k} + \frac{1}{h_d{}^{11}} + \frac{1}{h^{11}}$$

where q = rate of heat transfer, B.t.u. per hr.
U = overall coefficient of heat transfer in B.t.u. per hr. per sq. ft. per deg. F.
A = area of heat transfer surface in sq. ft.
T_i = Bulk temperature of warmer fluid, degrees F.
T_0 = Bulk temperature of cooler fluid (sludge), degrees F.
h^1 = film coefficient between hot liquid and hot surface of heat exchanger in B.t.u. per hr. per sq. ft. per deg. F.
$h_d{}^1$ = scale coefficient on hot side of heat exchanger in B.t.u. per hr. per sq. ft. per deg. F.
$h_d{}^{11}$ = scale coefficient on cool side of heat exchanger in B.t.u. per hr. per sq. ft. per deg. F.
h^{11} = film coefficient between cool surface of heat exchanger and sludge in B.t.u. per hr. per sq. ft. per deg. F.
k = thermal conductivity of heat exchanger wall in B.t.u. per hr. per sq. ft. per deg. F. per ft. thickness
x = thickness of wall of heat exchanger in feet

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SLUDGE HEATING METHODS—A DISCUSSION

By Willem Rudolfs

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Although Mr. Miles has not taken into consideration the question of heat losses from digestion tanks, such losses have some bearing on the methods of heating employed. Incompletely insulated or poorly protected tanks require a greater heat supply and are subject to greater fluctuations in heat losses than well insulated tanks. With the possible use of higher temperatures in the range of thermophillic digestion heat losses increase. When preheating methods of sludge are utilized the question of preventing heat losses is even more important.

Laboratory experiments made some years ago showed that the rate of heat loss from sludge varied directly as the difference in temperature between the heated material and the surrounding air. The rate of heat loss was practically the same from fresh solids and ripe sludge. No difference in the rate of heat losses from sludges ranging in concentrations from 4 to 11 per cent were observed.

Large scale experiments with an operating digestion tank 30 ft. in diameter and 17 ft. deep, insulated in the usual way by an earthen embankment and sludge heated to about 87° F., showed that of the total heat supplied, 70 per cent was utilized and 30 per cent lost. The heat required to maintain the digestion tank at a given temperature varied directly as the temperature difference between the tank and the normal ground temperature.

The heat from the digestion tank did not penetrate the same distance in all directions into the surrounding soil, probably due to wind action and soil drainage. The heat from the sides of the tank travelled only in a horizontal direction. Preheating of sludge outside the digester must be materially higher than the actively digesting material.

Mr. Miles indicated that stirring devices are utilized primarily to induce more uniform gas production. In effect, such stirring devices are usually located near the bottom of the tank and aid materially in the concentration of the sludge and may be of some benefit in increasing convection currents and thus aiding in the heat distribution throughout the mass.

Normally the contents of the digestion tank consist of two distinct layers of different solids concentrations and different temperatures. The temperatures within the layers are practically constant horizontally and vertically. The difference in temperature between the layers averaged about 10° F. over a period of one year of careful measurement, the hotter layer being toward the bottom. It appears, therefore, that center heating devices do not need to be rotating in order to induce convection currents as an aid for heat distribution.

The film coefficient of heat transfer from the testing coils to the sludge is very low, about $\frac{1}{10}$ that of water. It should be remembered that the cooling constant of sludge is also much lower than water, in other words, the sludge retains the heat longer and to a higher degree than water, which in turn aids in maintenance of a uniform distribution of heat no matter which heating device is employed.

Mr. Miles stresses the tendency for a highly insulative scale to form on the outside of the coils unless the temperature of the testing water is kept below 130° F. This recalls a series of simple laboratory experiments made about 1927 and which were never published

except as a commentary statement that scale formation is rapid when sludge is heated to 140° F. and to be on the safe side the incoming hot water should not be over 135° F.

The writer does not know of any experiments which have confirmed these simple laboratory experiments nor has he seen a compilation of heating water temperatures and rates and quantities of scale formation from operating plants. Apparently practice has taken this statement and found that no undue scale formation occurs with temperatures below 130° F. Further study may be warranted to establish more precisely the temperature limits. Such a study would be of particular interest in connection with the submerged gas burners and preheating devices.

Attention should be called to the fact that addition of steam to raw sludge prior to introduction into the digesters, as well as preheating of sludge through steam and hot water jacketed bundles of pipes, have been practiced at various places for a number of years.

From a comparison of sludge heating methods Mr. Miles appears to favor the external type of heater over the internal heating coils. It may be expected that the designing engineers will scrutinize the results obtained rather than act upon expectations, but there is no doubt that the heating methods most commonly employed can be improved, modified or varied to advantage and that newer methods are worthy of careful study.

SLUDGE HEATING METHODS—A DISCUSSION

By A. M. Rawn, Vinton W. Bacon and Harvey F. Ludwig

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At Prof. Miles's invitation, we have prepared this brief discussion of sludge heating with live steam, with particular reference to operating experience with this method at the Joint Disposal Plant of the Los Angeles County Sanitation Districts.

As described by Prof. Miles, the sludge is heated at the Districts' plant by injecting live steam into the hopper of the sludge concentration tanks while the raw sludge is being withdrawn and pumped to the digesters. Very little heat is lost from the digestion tanks, and no additional heating is required. This system has been continuously in operation since 1942 and has proven easy to operate and practically free of trouble. The one minor difficulty encountered resulted from injecting the steam through a 3-in. open-end pipe; this caused considerable "booming" noise and also cracking of the concrete floor immediately below the pipe outlet. This difficulty, however, is easily overcome by use of multiple steam outlets of small size.

Steam heating of sludge has also been successfully practiced for more than a year at the San Diego, Calif., sewage treatment plant, according to Supt. Eric V. Quartly. In this instance a 6 ft. by 6 ft. by 6 ft. concrete box, open at the top, was constructed on the roof of the control house between the primary and secondary digestion tanks. An overflow weir maintains a 5 ft. sludge depth in the box, and raw sludge is added through a single pipe in the center. Steam is supplied through a 4-in. transmission line into a header comprising four 3-in. pipes. These 3-in. pipes are sealed at the ends but have been perforated near the ends, with eight $\frac{3}{16}$-in. holes in each pipe. This multiple small-

sized outlet system has resulted in operation free of noise and vibration.

Steam is generated in a 75 h.p. Scotch marine boiler, and a pressure of only 3 p.s.i. is sufficient to overcome transmission line losses and the static head of the sludge. No further sludge heating is needed at the digesters, temperatures of which are maintained throughout the year between 96° and 99° F. The raw sludge is pumped almost continuously from the clarifiers, to the digesters so that steam may be added continuously and in constant amount. (Such steady operation might not be practical in small plants.)

There are other methods for heating sludge with steam. In closed sludge transfer systems, where sludge is pumped directly from sedimentation tanks to digesters, steam may be injected into the pump suction lines, with the advantage that only low-pressure or heating-class boilers would be necessary. When steam is injected into pump discharge lines, higher pressures are of course required, with the result that power-class boilers may have to be installed. Only in larger plants would high-pressure systems be economical, but in these cases good design might take advantage of the pumping power of the steam jet.

Satisfactory digester temperatures can also be maintained by injecting the steam through a few outlets directly into the digester. This scheme should be particularly suited to small plants, because it permits continuous steam injection and therefore smaller capacity boilers. It is the writers' belief that no appreciable sterilization effects can result from such injection, since the areas which might actually be sterilizing temperatures are relatively very small. The volume of sludge which might be sterilized is negligible, and will be quickly reseeded by the remaining mass. In the experimental work preceding installation of the Los Angeles County Sanitation Districts' steam system, Dr. Richard Pomeroy found that no appreciable sterilization resulted from direct injection.

The thermodynamics involved in the various methods of steam injection are simple. The heat exchange is direct from steam to sludge, without the complications that arise from use of heat exchangers. The problems of conductance through the metal walls of an exchanger, through the scale which inevitably forms upon the walls, and through the films adjacent to the scale or wall do not exist.

There does exist loss of heat in the present type of steam heating systems at the heat generating plant through boiler stacks, and a small amount in steam transmission lines, but these losses are common to any system where the processes of heat generation and dissipation are separated or where hot flue gases are allowed to escape.

The most efficient heating system will be that in which the heat is generated and dissipated within the sludge mass, and for this reason the recently advanced idea of burning a fuel in direct contact with the sludge (the submerged gas burner with open flame described by Keefer) offers considerable promise. At the present time much work remains to be done before this idea can safely be incorporated into plant design.

PRESENT STATUS OF SLUDGE GAS UTILIZATION *

By Richard H. Gould

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For a comprehensive discussion of the status of sludge gas utilization it would be necessary to canvass the experiences of literally hundreds of important installations in this country and abroad where sewage sludge is digested and the resulting gas is collected and utilized. Rather than attempting such an arduous and time consuming task, the present contribution will be confined to the experiences in the sewage works of New York City during the past ten years.

It is important to bear in mind that sludge digestion and gas utilization is but one of several alternate methods that may be available in the disposal of sewage solids. Its adaptability and economic feasibility will vary considerably in different localities and with special conditions that always are present in each particular project.

Much depends on the possibilities of disposal of the ultimate residues. If disposal at sea is available there is one set of circumstances. If large tracts of cheap land may be had the possibilities are different. Fertilizer manufacture may be attractive to some, while incineration may be the best compromise to others. A determinant in many cases will be the economic availability of possible treatment plant sites, their size and degree of isolation.

In New York City in recent years the trend has been definitely toward the digestion of sludge and the utilization to the extent considered practical of the resulting gases. New York City's largest plant, on Wards Island, and the first of its modern plants to be placed under construction, is the only exception. Here the solids removed from the sewage are shipped to sea in a fluid state with no treatment other than the decantation of excess liquids.

Of the newer plants in operation all provide for sludge digestion. At Coney Island, Tallmans Island, Bowery Bay and Jamaica the digester gas is utilized to generate power and heat, and at one small plant (City Island) the gases are used for heat only. The same condition will obtain in the 26th Ward plant now under construction and those for which plans have been made or are under way. Included in the latter category is the extension of the present Wards Island plant to over twice its present capacity.

Conditions Favoring Digestion in New York Plants

It may be of general interest to outline some of the conditions that make sludge digestion adaptable to the New York problem.

Of the seventeen locations in use or adopted for future plants there are only four that are distant as much as 1,000 ft. from residential areas; many are much closer, hence odor control and aesthetics are of paramount importance. Control of large scale fertilizer production has not yet been developed to a stage where it could be safely practiced in most of these locations.

One distinct asset is the city's location on the ocean and the economy, simplicity and lack of offense with which sewage solids can be disposed of at sea. The disposal of the voluminous raw solids from the activated sludge

* Presented at Nineteenth Annual Meeting, Federation of Sewage Works Association, Toronto, Canada, October 7–9, 1946.

plant at Wards Island is accomplished at an operating cost with city-owned vessels of about 12 cents per ton of liquid sludge, or about $2.64 per ton of dry solids. This is, of course, much cheaper than local costs would be for filtration and incineration.

There is a problem, however, in the control of odors at the plant site in the storage and loading of the raw sludge on the vessels. Provision has been made for the use of ozone in the sludge storage building and for the use of activated carbon at the vents of the sludge tanks on the vessels, but the latter was found difficult to maintain in effective condition and has been discontinued. In general, however, no serious trouble from odors has developed.

It has been found that when the combined primary and activated sludges are digested the destruction of organic matter and the greater concentration of the solids result in a volume of residue of about one-half the bulk of the raw sludges. The resulting saving in the shipping cost of the residues is enough to pay for the capital and differential operating costs of digestion tanks. Digestion tanks can be operated without offense. The hazards of handling raw sludges are thus avoided and at no additional cost. There is substantial value in the large volumes of methane gas that are collected as a by-product of digestion. It is the utilization of this by-product, secured at substantially no additional cost, that is the subject of the present discussion.

Gas Utilization in New York Plants

Coney Island

New York City first embarked on the digestion of sludge and the utilization of digester gases at the Coney Island plant in 1936. The first installation here was designed for a flow of 35 m.g.d. This plant was laid out to provide chemical precipitation and chlorination during the summer and plain sedimentation only during the winter. Eight digestion tanks with gas holder type covers of our own design were provided.

What was then considered a bold step was taken in that entire reliance for the power requirements for pumping and all other uses was placed on three 300-h.p. gas engine generator sets. No provision was made for the purchase of electricity from an outside source, however, provision was made for the purchase of utility gas in case of a possible deficiency of digester gas.

In 1941 the capacity of the plant was doubled. Six new digesters were added. These were fitted with covers floating on the sludge, as the gas storage in the older plant was considered adequate. Three gas engine generator units, each of 920 h.p., were added. The digestion tank capacity now totals 1,200,000 cu. ft., which is 2 cu. ft. per capita on the design population of 600,000. Gas storage amounts to 400,000 cubic feet.

Gas utilization at the Coney Island plant has been eminently satisfactory. Sewage has been lifted 40 ft. and auxiliaries and services maintained with but a trivial amount of utility gas being purchased. There is no means to record surplus gas wasted, but gas utilized and metered represents less than half of that which should be recovered from the volatile matter added to the digesters, based on experience in other city plants. In ten years of operation there has been no flooding of the sewers due to power failure. Heat recovered from engine cooling water and exhaust gases has been adequate for heating the digestion tanks and plant buildings except on a few extremely cold days when digester gas was used under the heating boilers.

Tallmans Island

The second digester installation to go into service was at Tallmans Island in 1939. This plant of 40 m.g.d. ca-

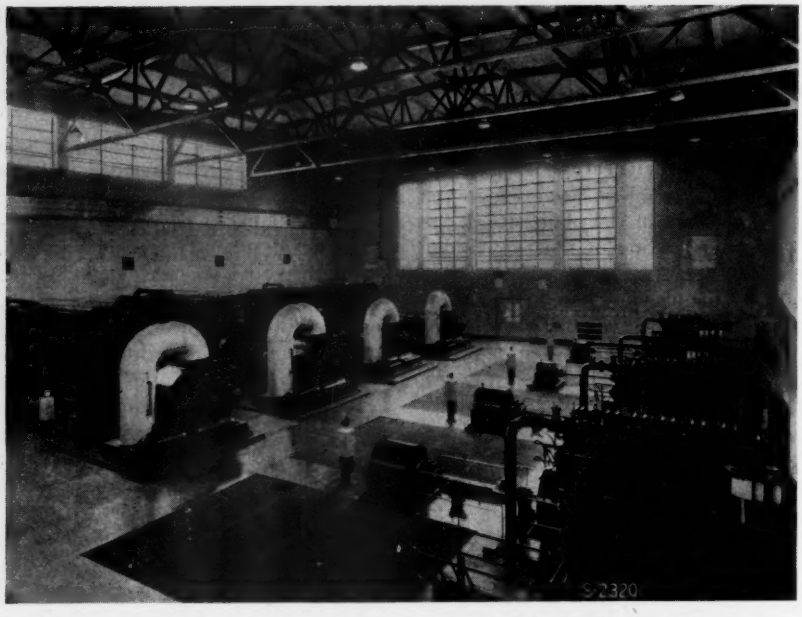

FIGURE 1.—Gas engines driving pumps and compressors at Tallmans Island sewage treatment plant, New York City.

pacity is of the activated sludge type. It was felt that the power requirements of this process would exceed the potential power that might be secured from gas utilization. The four digestion tanks, providing 705,000 cu. ft. capacity, were therefore fitted with floating covers and no gas storage was provided as little excess gas over the demand was expected.

Four gas engines were directly connected to positive displacement blowers for the air supply and four others by means of angle gears to the main vertical centrifugal pumps working against a 39-ft. head. Facilities were provided to make up any deficiency in gas production by utility gas. Electric power for lighting and auxiliary equipment was purchased from the power company. The eight engines have total rating of 3,620 horse-power.

Gas production at Tallmans Island has more nearly met power requirements than was expected. There are many days when full engine requirements are met and no gas is purchased. The annual average for 1945, for example, shows that of the gas produced 3 per cent was wasted and the remainder met 91 per cent of the engine demand. About 1.4 per cent of all gas was used for heat during cold weather. Taking into account the electric power purchased for auxiliaries as well as the requirements of the main pumps and blowers, the gas produced accounted for a little over 75 per cent of the total power requirement for the plant and all but a very small part of the heating of digesters and buildings.

Bowery Bay

The 40 m.g.d. activated sludge plant at Bowery Bay was placed in full operation in 1942. Four digestion tanks provided 728,000 cu. ft. capacity for a population of 308,000. They were fitted with gas holder type covers giving 206,000 cu. ft. of storage.

Negotiations with the utility company for outside services were not entirely satisfactory. It was not practicable to bring in a supplementary source of gas and the company opposed cross connections on the electrical boards that would allow alternate operation of the main pumping and blower units either by generated or purchased power. This has resulted in a lack of flexibility and some unbalance in the proportioning of the capacity of units on the gas engine half of the plant.

Two 800-h.p. gas engine generating units were installed. While in some months they may produce nearly 70 per cent of the total power required at the plant, the annual averages show only about 45 per cent of this requirement. About 7 per cent of the gas produced was used under the heating boilers.

Jamaica

The 65 m.g.d. activated sludge plant at Jamaica started operation in 1943. This plant designed for 500,000 people, has twelve digestion tanks of 1,618,000 cu. ft. capacity with gas holder covers of 400,000 cu. ft. capacity. There are three gas engine generator units each of 1,450 b.h.p.

The arrangements with the utility company at this plant are much more satisfactory than at Bowery Bay. Here there is a utility gas connection to supplement the digester gas if necessary. The main pumping and blower units may be supplied with either purchased electricity or that generated from gas.

Gas production here was sufficient in 1944 and 1945 to supply 85 per cent of all the power used and on some days there has been a surplus. It should be noted, however, that for the period in question the plant was operating with low solids in the aeration tanks under the system developed and described under the term "modified sewage aeration." Air consumption has been about 0.4 cu. ft. per gal. of sewage. Heat requirements for the digesters and buildings were met for the most part by heat recovered from engine operation. Only about 1 per cent of the total gas produced and purchased was burned under the heating boilers.

Design Practice

There is nothing particularly unique in the New York City sludge digestion practice. In the four plants described above the tanks are circular, varying in diameter from 54 ft. in the early Coney Island plant to around 80 ft. for the others. They have conical bottoms with side water depths from 24 to 30 feet. Temperatures are maintained at from 85° to 90° F. by means of pipe coils in the tanks. The hot water circulating therein comes from the water jackets of the engines, the heat exchangers from the engine gases and may be supplemented by gas or oil fired boilers. Part of the tanks are used as primary and others as secondary digesters with surplus liquid decanted from the secondaries.

The new designs provide for larger tanks. In some cases diameters will be as much as 120 ft. and side water depths up to 40 feet. In these larger tanks multiple inlets will be provided to assure distribution and mixing of solids in the tanks. Provisions for positive circulation are also to be made. At the proposed Hunts Point plant preheating of sludge before discharge to the digesters is called for.

The quality of the digester gas is quite uniform, averaging about 64.4 per cent methane with plus or minus variations of from 2 to 3 per cent. Its heat content is about 654 B.t.u. as compared to the local utility gas of about 540 B.t.u. The sulfur content averages about 2.4 gr. per 100 cu. ft. and has not required any special treatment.

Dual Fuel Engine at Tallmans Island

The engines are of the heavy duty slow speed type. Many of them are

designed so that they can be rather easily converted to the diesel cycle. Indeed an interesting recent development is based on the conversion of one of the blower engines at the Tallmans Island plant to the full diesel cycle and its operation with oil and digester gas as fuel.

The engine at Tallmans Island has been under test operation for over a year. It is known, of course, that the diesel cycle permits approximately 25 per cent greater power recovery from a gaseous fuel as compared to the Otto cycle of the ordinary gas engine. It has been found elsewhere that in order to ignite a gas uniformly at diesel pressures it was necessary to inject a small amount of oil with the gas. It was found that successful operation with digester gas was possible with the injection of diesel oil in the amount of from 5 to 7 per cent of the heat value of the total fuel used. The engine performed well with the use of 100 per cent oil or any combination of oil and gas between these limits. Economies in fuel consumption were demonstrated to be quite as anticipated.

This new combination seems to offer great advantages in the utilization of digester gases. The greater economy of the diesel cycle will make the gas go further and in most cases would seem to stretch the supply so that all normal power requirements can be met. Should there be a deficiency of gas during the first months of operation, or later for any reason, the cost of power using oil alone as a fuel would be less than power from purchased gas or from electricity that is subject to the usual demand charges.

The possibilities of this new combination are so promising that one existing contract for gas engines for the 26th Ward plant has been modified to convert these engines to the dual fuel Diesel type. Provision is being made in new plants under design for installation of this new type. In these new units the supercharging of gas fed to the engines will probably be provided for, thus further increasing the fuel economy and increasing the capacity of units of equivalent size.

Conclusion

The utilization of sludge gas does undoubtedly call for considerable extra effort in plant design and operation. To be successful it presupposes intelligent layout and proper operation and maintenance. With a power installation that is reasonably well loaded so that the capital charges are not out of line there is a very substantial margin of cost in favor of the utilization of this by-product of sludge digestion.

SLUDGE GAS UTILIZATION—A DISCUSSION

By A. M. Boehm

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Since Mr. Gould's very informative paper covers utilization of sewage sludge gas in many ways, some of which are foreign to the writer's field, these remarks will be confined to that portion which deals with gas utilization for power purposes and, more specifically, to the dual fuel engine.

Perhaps it would not be amiss at this time to define a dual fuel engine as it is now understood. Briefly, it is an internal combustion engine which consumes gaseous fuels, using compression pressures approximating those of a full Diesel oil engine and employing a small amount of fuel oil called "pilot oil" to ignite the compressed gas and air charge.

An engine of this type may take a number of forms, depending on the field conditions to be met. It may be:

1. A full dual fuel engine. This is the terminology used to designate an engine that must be capable of operating on all fuel oil or all gas, plus pilot oil or any percentage of fuel oil and gas at the option of the operator. It must do any of these things without shutting down or being relieved of load. A further refinement which has a great deal of appeal for sewage sludge gas power applications is one that enables the engine always to operate to the fullest extent of its availability on gas, but, should the gas supply diminish or vanish, will automatically make up the deficit by having the engine governor divert more and more of the fuel requirements to oil. The latter is the final arrangement of the engine as seen today at the Tallmans Island plant.

2. A pilot gas engine. This would be the form used where the supply of gas is continuous at an attractive price and no condition would be encountered that would necessitate changing over to fuel oil. The only fuel oil used would be that supplied for ignition by a small pilot oil pump. This was the first change that was made to the Tallmans Island engine from its original arrangement as a low compression spark ignition engine.

But, one may ask, why a dual fuel engine at all? Why change from the generally accepted low compression spark ignition engine that has given such a good account of itself in so many sewage treatment plants? The answer may be summed up in the words—"higher efficiency." It has been evi-

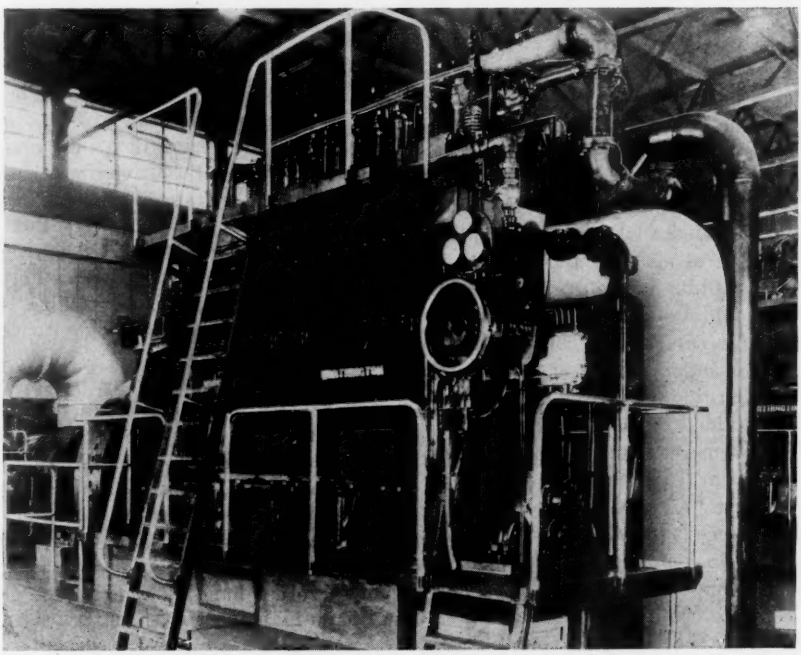

FIGURE 1.—Converted dual fuel engine driving compressor at Tallmans Island sewage treatment plant, New York City. Rated at 500 h.p. at 327 r.p.m.

dent for many years what high compression has done to increase thermal efficiency in the Diesel oil engine, but it has taken too long to realize that the same treatment could result in the same benefits where gas is the fuel instead of oil. Commendation is due the English engine manufacturers for pioneering the high compression gas engine.

To be specific about the benefits accruing from high compression, there has been obtained at Tallmans Island a brake horsepower-hour on 6,815 B.t.u. total of gas and pilot oil operating at only 85 per cent of the engine full load rating as a dual fuel engine. This would compare with about 9,100 B.t.u. per b.hp.-hr. on a spark ignition low compression engine, or about 25 per cent less fuel per b.hp.-hr. This in itself is full justification for this type of engine, but when additional benefits, such as the ability to burn oil or gas or both simultaneously, are considered, it is easily seen that here, indeed, is another vastly useful device for use in sewage treatment plants.

Another way of expressing the higher efficiency in terms of the specific job the engine has to do at Tallmans Island is as follows: As a spark ignition low compression gas engine, it takes 1 cu. ft. of gas to pump 100 cu. ft. of air, while the dual fuel engine will pump 125 cu. ft. of air with the same quantity of gas plus pilot oil.

It should be pointed out here that the above results have been achieved on a non-supercharged engine. With turbo-charging, improved results have been obtained in shop tests.

A few more statistics from the experiences at Tallmans Island might be of interest. Of these, a representative heat balance is probably of the greatest import, since not only heat to useful work is important, but also the heat rejected to cooling water and exhaust. It is from the last two items that by-product heat is usually recovered, with which to heat the sludge in the digesters. The dual fuel heat balance would average something like this:

Heat converted to work	36%
Heat rejected to jacket cooling water and lube oil	26%
Heat to exhaust, radiation, and friction.	38%
Heat to exhaust alone	34%

Pilot oil requirements have consistently averaged lower than 7.5 per cent of the total B.t.u. per b.hp.-hr.

The engine has been tested at speeds as low as 200 r.p.m. and as high as 360 r.p.m., whereas its rated speed is 327 r.p.m. Inasmuch as this engine drives a blower supplying air to the aeration tanks, there has been restriction to a minimum of about 6.5 p.s.i. discharge pressure, due to inability to force air through the aeration blocks at less pressure, and to a maximum of slightly over 8 p.s.i. pressure due to blower limitations.

Tallmans Island operation has given a chance to observe characteristics on both sewage sludge and manufactured gas separately. The latter has been the alternate source of gas for the spark ignition low compression gas engines originally installed; this, of course, would be unnecessary in a new plant starting with dual fuel engines, since the ability to operate on fuel oil provides the alternate fuel. In addition to these two gases, factory test runs have been made on a mixture of natural and manufactured gas, yielding invaluable experience with a wide variety of gases.

It has been found that each type of gas provides operating characteristics differing from other types. Straight manufactured gas with high free hydrogen content imposes a limit on the permissible compression pressure, since the free hydrogen ignites more readily and detonation occurs at lower loading. On the other hand, sewage sludge gas with its high inert CO_2 content acting as an ignition suppressive permits of higher compression pressures, but requires more pilot fuel oil to initiate,

propagate and sustain ignition of the gas and air charge.

During all the pioneering runs which Worthington has made in the United States on various gases, it is fortunate that the original conception of this engine for high efficiency contemplated and incorporated the use of individual gas regulating valves to each cylinder under governor control, and a pilot fuel oil pump separate from the main fuel injection pumps, as this has given an opportunity to adjust both gas and pilot oil for optimum performance. It has been kept in mind constantly that for sewage sludge gas engines a minimum of pilot oil is not only desirable, but economically necessary, since pilot oil is fuel that represents an operating expense, whereas the sewage sludge gas is a no-cost, or at most, very low cost fuel.

It is the writer's considered opinion that in new future sewage works involving a number of engines for power generation purposes, all engines need not be of the ultimate dual fuel type, but only as many of this type are necessary to provide initial plant operation and continuity of operation. Thereafter in the event of diminishing or vanishing gas supply; the remainder may very well be of the spark ignition low compression type, where an abundance of gas exists.

At this time public acknowledgment is made of our appreciation of the wholehearted cooperation of Mr. Gould and his colleagues in the New York Department of Public Works for providing the facilities at Tallmans Island for the furtherance of knowledge of the dual fuel engine. In particular, we are indebted to Mr. Harry Roth, Superintendent of the Tallmans Island plant, who has assisted in the research in no small measure and who took a keen interest in all results.

PHOSPHATES IN SEWAGE AND SLUDGE TREATMENT

II.—EFFECT ON COAGULATION, CLARIFICATION AND SLUDGE VOLUME *

By Willem Rudolfs

Chief, Department of Sanitation, New Jersey Agricultural Experiment Station, New Brunswick, N. J.

Coagulation experiments with different types of sewages and groups of substances present in sewage showed that the soluble or colloidal sol, and not the coarse dispersed material, is mainly responsible for the coagulant demand. Urine present in sewage contains substances which absorb iron coagulants or interfere with the action of coagulant. Additions of urine to sewage result in poorer clarification with iron salts and require increased dosages of iron. Various pure organic substances known to be present in urine, including a phosphoprotein, did not increase the iron coagulant demand materially.

Studies made on the action of lime in the clarification of sewage have brought to light some interesting phenomena. The action of lime in clarification of water and sewage has generally been attributed to the formation of calcium carbonate on account of the neutralization of bicarbonates and carbonic acid with the lime. The resultant floc of carbonate was then considered responsible for coagulation.

In our studies it was found that 95 per cent of the turbidity in sewage is removed before appreciable calcium is precipitated from solution. This is contrary to the concept that the precipitated lime is responsible for coagulation. It is a well-known fact that lime lowers the iron coagulant demand of sewage. Since addition of urine to sewage increases the ferric chloride demand and combinations of lime and iron salts reduce the coagulant demand, the question arose whether lime additions without ferric chloride would behave similarly.

Effect of Urine on Lime Demand of Sewage

Series of experiments were made with domestic sewage to which 10 ml. of urine were added per liter, for comparison with results on sewage receiving 10 ml. of distilled water per liter. The samples were treated with hydrated lime in varying quantities, flocculated and settled, and the supernatant liquor was analyzed. A comparison of the results obtained is presented in Table I. In previous experiments, it has been shown that sewages with relatively low electrical resistance clarified at a lower pH value than sewages with high electrical resistance. As will be noted, the addition of 1 per cent urine decreased the electrical resistance of the sewage. Moreover, the addition of urine lowered the pH value at which clarification took place. This gave a clue to the often observed fact that strong sewages are relatively easier to coagulate and require relatively less coagulant than weak sewages.

The results show that the addition of urine to the sewage lowered the lime demand. In other words, the results obtained with lime were opposite to those obtained with iron coagulants.

* Journal Series Paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Sanitation, New Brunswick, N. J.

TABLE I.—Effect of Urine on Lime Demand of Sewage

Ca Added (p.p.m.)	Turbidity (p.p.m.)	Resistance (Ohms)	pH	HCO_3^- (p.p.m.)	CO_3^- (p.p.m.)	Total Alkalinity*	Sludge Volume (%)
	Without Urine						
0	260	1560	6.9	179	0	179	2.3
10	190	1620	7.4	198	0	198	1.6
20	120	1575	6.2	210	20	230	2.3
30	116	1475	8.6	175	69	244	2.2
40	100	1480	8.9	141	128	269	2.2
50	94	1560	9.2	99	193	292	3.1
60	93	1580	9.3	61	244	305	3.4
70	43	1550	9.5	56	224	280	3.5
80	26	1620	9.6	35	224	259	3.4
	With One Per Cent Urine						
0	226	1150	7.0	228	0	228	2.9
10	132	1120	7.3	248	0	248	2.3
20	100	1200	7.9	264	0	264	3.5
30	156	1075	8.3	262	15	277	3.9
40	70	1120	8.5	202	57	259	5.1
50	50	1175	8.7	177	91	260	5.2
60	<20	1125	8.9	148	110	259	6.2
70	<20	1150	9.1	107	162	269	7.3
80	<20	1150	9.3	99	183	282	9.2

* Total alkalinity, carbonates and bicarbonates expressed as $CaCO_3$.

Although the initial total alkalinity in the sewage with urine was higher than that in sewage without added urine, the alkalinities did not increase to the same extent when lime was added. This would seem to indicate a loss of calcium by precipitation with some substance contained in the urine. From the changes in bicarbonates and carbonates found, there occurred a shifting in precipitation with increasing quantities of lime. When the carbonates found in the two examples are again compared with the degree of clarification, changes are apparent. Another outstanding fact is the remarkable increase in sludge volumes, which were more than doubled by the addition of urine.

Urine Constituents and Lime Demand

The general effect of urine on sewage coagulation led to the question: Which constituent of urine was responsible? The effect of various fractions of urine upon the lime demand of sewage was determined by adding specific fractions such as ether and carbon tetrachloride extracts, filtrates from lime-treated sewages, additions of urine made alkaline with NaOH or $Ca(OH)_2$, filtrates neutralized with alkalies, urine and filtrates treated with HCl, soluble and insoluble ash, additions of urea or uric acid, etc. The usual flocculation and sedimentation procedures were followed and final turbidities determined. The experiments were conducted in such a way that the amount of lime used was sufficient to produce turbidities of less than 20 p.p.m. with the sewage to which urine was added, and which would also produce turbidities over 30 p.p.m. without the addition of urine. The main reason for adopting this method was to make it easier to compare the results.

A study of the results obtained showed definitely that the constituent of urine which was effectively lowering

the lime demand of sewage was a compound that was precipitated with calcium hydroxide. The compound was not precipitated by sodium hydroxide, nor was it extracted by organic solvents. It was unaffected by heat and unaltered by acid. From this evidence it was concluded that the compound responsible was inorganic.

Analyses for the principal inorganic constituents of urine were as follows:

Cl	1,675 p.p.m.
Na	3,350 p.p.m.
K	1,675 p.p.m.
Ca	175 p.p.m.
Mg	126 p.p.m.
SO_4 as SO_3	1,675 p.p.m.
PO_4 as P_2O_5	2,075 p.p.m.
NH_3-N	475 p.p.m.

Of the constituents listed, phosphates would be precipitated with lime water.

Effect of Soluble Phosphate on Coagulation

To determine the effect of soluble phosphates on coagulation and the lime demand of sewage, a series of experiments were made. Analyses of various sewages showed that the P_2O_5 content varied from 5 p.p.m. in a very weak sewage to 32 p.p.m. in a strong sewage. The P_2O_5 content of a sample of domestic sewage composited over a 12-hour period was found to be 16.7 p.p.m.

As an illustration of the effect of soluble phosphates, an experiment with disodium-acid phosphate added to sewage as a source of phosphates is shown in Table II. The amount of this salt added was sufficient to raise the P_2O_5 content of the sewages by 20 p.p.m. This increase is approximately equivalent to the increase resulting from the addition of 1 per cent urine. The lime was added as a saturated solution. Flocculation was obtained by stirring for 30 minutes at 20 r.p.m., followed by quiescent settling for one hour for clarification.

The results show that clarification was increased with urine and phosphates, that 20 p.p.m. of disodium-acid phosphate produced practically the same result as 1 per cent urine containing approximately the same amount of phosphates, and that the lime demand was reduced by at least 25 per cent. Both had a similar effect on the sludge volumes produced. The sludge volume with equal quantities of lime was nearly doubled by the phosphate. This increase in sludge volume was caused by the production of a thinner sludge and not by removal of greater quantities of suspended solids. This

TABLE II.—Effect of Soluble Phosphate and Urine on Coagulation and Lime Demand

Added	Ca (p.p.m.)	pH	Resistance (Ohms)	Turbidity Remaining (p.p.m.)	Sludge Volume (%)
Sewage Alone	0	7.30	1150	109	2.1
	50	8.90	1175	51	3.7
	60	9.05	1195	31	3.3
	70	9.20	1225	27	3.4
	80	9.30	1220	<20	3.5
1% Urine	30	8.45	745	61	3.1
	40	8.60	775	37	4.5
	50	8.70	825	26	4.7
	60	8.80	835	<20	5.8
20 p.p.m. P_2O_5 ($Na_2HPO_4 \cdot 12H_2O$)	30	8.45	1070	50	2.6
	40	8.65	1100	37	5.0
	50	8.80	1125	23	5.9
	60	8.95	1150	<20	6.4

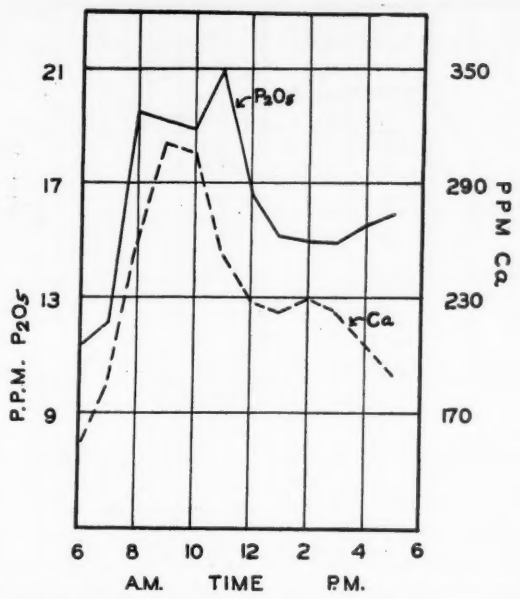

FIGURE 1.—Relation between lime requirements and P_2O_5 present in sewage.

phenomena will be discussed later in more detail. The urine and phosphate decreased the electrical resistance, but the decrease by urine was much greater than that produced by the phosphate; however, this could be expected in view of the salt content of urine.

Again attention is directed to the fact that optimum clarification of the sewage with urine and phosphate additions occurred at an appreciably lower pH value than the optimum clarification of sewage alone. Usually, clarification of sewage with lime occurs at a pH of about 9.4. When phosphate or urine is added, clarification occurs at a pH of about 8.8. This indicates that either the clarification process has been altered by the addition of phosphates or the pH values are not so important as has been supposed.

Relation of Phosphates in Sewage to Lime Requirements

The quantities of lime required to obtain optimum clarification have been plotted against the P_2O_5 contents of sewage samples collected between 6 A.M. and 5 P.M. (Figure 1). There is a general relationship between the quantities of lime required and the strength of sewage. The quantity of lime required varied directly with the P_2O_5 content of the sewage.

This relationship was even more pronounced between electrical resistance and quantity of calcium required, which is illustrated by results obtained in another run (Figure 2) where the lime demand is compared with electrical resistance and ammonia content. Since the total salts determine the electrical resistance, it is obvious that the close relation between resistance and lime required for optimum coagulation indicates that salts other than phosphate compounds also play a role, although of minor importance.

The most important salts affecting coagulation are the phosphate compounds. Theoretically, it would seem that an increase in strength of sewage, *i.e.*, increase in phosphates, should decrease the amount of lime required for

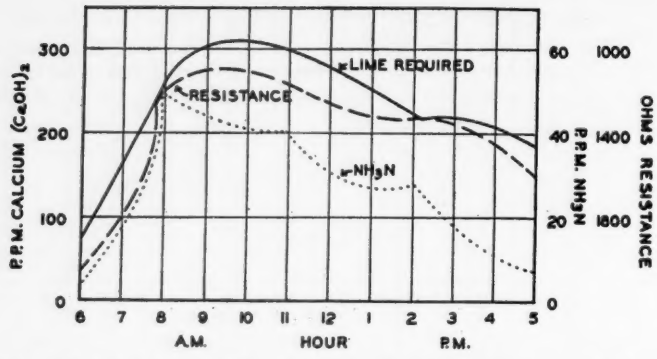

FIGURE 2.—Relation between lime requirement, electrical resistance and ammonia content of sewage.

coagulation. Calculations show that for a given quantity of P_2O_5 the lime requirement was practically constant, amounting to approximately 15 p.p.m. Ca for each part per million of P_2O_5 found in the raw sewage. If it is assumed that the lime demand varies directly with the quantity of suspended solids in the sewage, and if the calcium demand per part per million of suspended solids to effect complete clarification of the sewage is plotted against increasing strength and subsequently increasing quantities of P_2O_5 in the sewage (Figure 3), it is evident that the calcium demand per unit of suspended solids decreases with increasing suspended solids and P_2O_5 content.

This does not mean, however, that the P_2O_5 content of the sewage is directly proportional to the increase in solids concentration. Part of the phosphates are in solution and there is a tendency for the P_2O_5 content to de-

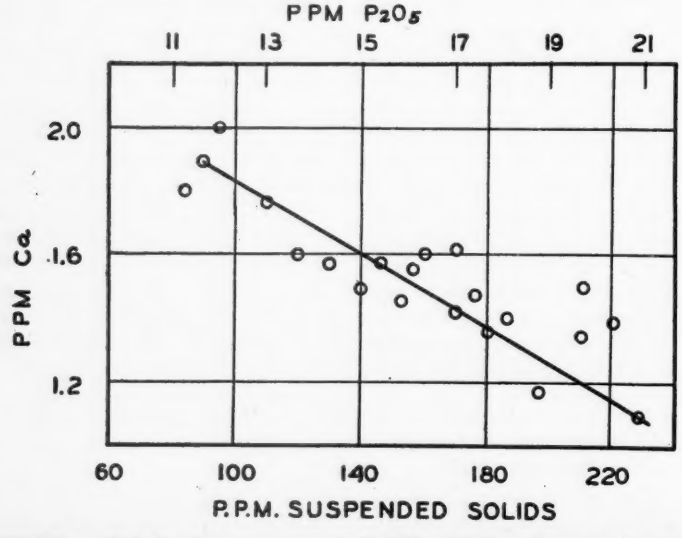

FIGURE 3.—Relation between suspended solids and lime demand of sewage.

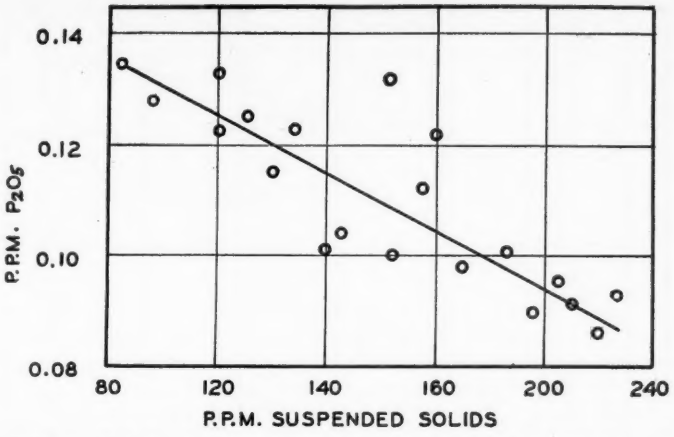

FIGURE 4.—Relation between suspended solids and P_2O_5 present in sewage.

crease relatively with the increase in suspended solids present in the sewage.

This is illustrated in Figure 4, where the P_2O_5 content per unit of suspended solids is plotted against increasing quantities of suspended solids. The results seem to indicate that with increasing strength of sewage more and more P_2O_5 is in solution. As will be shown later, the type of phosphate in solution is of importance in coagulation, and the decrease in calcium demand with increasing strength of sewage may possibly be attributed to the increasing quantities of phosphates in solution.

Effect of Phosphates on Clarification

The presence of relatively small quantities of phosphates appears to affect coagulation and clarification. The effect of the phosphates present on the removal of sewage solids and the rate of settling is presumably in relation to the quantities of phosphates present. It would be possible that additions of phosphates to a domestic sewage would reduce the removal of settleable solids and the rate of settling. Experiments with a number of weak and strong sewages, however, do not indicate such effects. Additions of from 5 to 20 p.p.m. of various phosphates indicated that some retardation in settling may take place during the first 5 to 10 minutes, but any such effect was lost after 30 minutes settling. It appears, therefore, that the quantities of phosphates normally present in sewage are sufficient to affect clarification and settling, if such an effect occurs. A study of the removal of phosphate from sewage by coagulants may throw light on the mechanism of the action of phosphates.

Precipitation of Phosphate with Lime

In these studies various types of lime were used; the lime was applied dry, as a slurry and in solution. The inorganic phosphates present in urine are primarily sodium and potassium salts. Different forms of these phosphates were added to raise the phosphate content of the water to about 20 p.p.m. as P_2O_5. The precipitates formed were flocculated for 15 minutes. The supernatant liquor was filtered and the phosphates were determined.

Typical results obtained with K_2HPO_4 and lime solution are shown in Figure 5. The P_2O_5 content of 21 p.p.m. was reduced to 2.6 p.p.m. with the addition of 25 p.p.m. CaO. In all cases, whether mono- or di-potassium phosphate was used, the amount of phosphate remaining in solution after

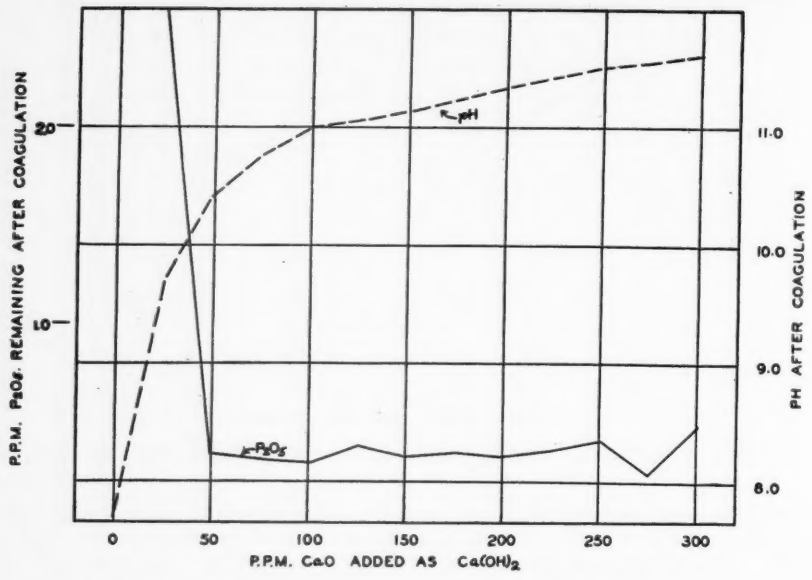

FIGURE 5.—Phosphate precipitation with lime solution.

coagulation became fairly constant after 50 p.p.m. CaO had been added. The pH values, measured after the precipitation occurred, increased fairly uniformly. The floc formed with lime additions up to about 50 p.p.m. was very small, rapidly increasing to a large fluffy floc as the dosage of lime increased.

Effect of Calcium and pH on Phosphate Precipitation

A series of experiments were conducted by adding $CaCl_2$ instead of lime solution to water. The pH values did not change materially and no floc was formed. It appeared that the pH was an important controlling factor. When the phosphate solution was adjusted with NaOH and then various quantities of $CaCl_2$ added in amounts up to the equivalent of 100 p.p.m. CaO, the results showed that large floc was beginning to form at about pH 10, when most of the phosphate was precipitated. For example, when the pH was adjusted and 100 p.p.m. $CaCl_2$ added, maximum phosphate removal and optimum size of floc was obtained at pH 10.8 (Table III); this was at the point where a minimum change in pH values occurred. The pH changes are clearly illustrated in Figure 6.

TABLE III.—Precipitation of KH_2PO_4 at Various pH Values with 100 p.p.m. $CaCl_2$

Initial pH	pH After Coag.	P_2O_5 After Coag. (p.p.m.)	Floc Formation
7.97	7.31	20.0	none
8.30	7.18	20.6	barely visible
8.42	7.23	20.2	very slight
9.00	7.21	19.6	slight
9.39	6.98	17.7	small
9.52	7.14	16.6	medium
9.64	7.11	14.7	larger
9.94	7.01	11.6	appr. 0.5 mm.
10.12	7.30	2.88	appr. 0.5 mm.
10.29	8.23	2.27	appr. 0.5 mm.
10.54	9.87	1.96	appr. 0.5 mm.
10.80	10.51	0.71	appr. 0.5 mm.
11.00	10.38	0.51	appr. 0.5 mm.
11.13	10.58	0.63	appr. 0.5 mm.
11.34	11.02	0.79	appr. 0.5 mm.
11.44	11.20	0.53	appr. 0.5 mm.

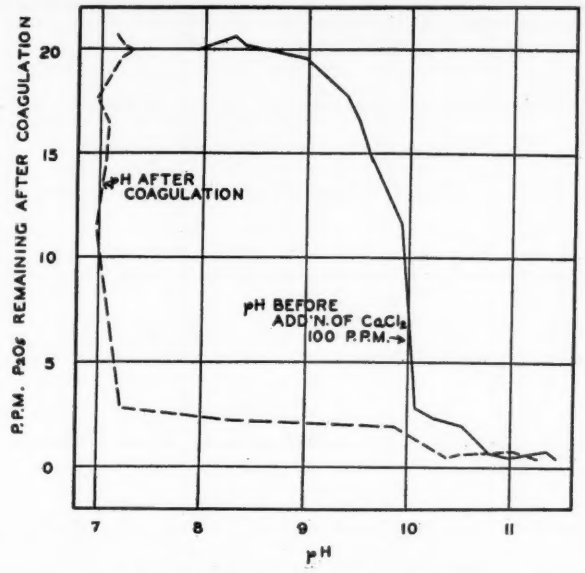

FIGURE 6.—Phosphate precipitation at various pH values with $CaCl_2$.

When the pH values were adjusted to 10.8 before varying quantities of $CaCl_2$ were added, a sizeable floc was formed with small quantities of $CaCl_2$ (25 p.p.m.) and about 80 per cent of the phosphates were precipitated. However, very large floc again was formed when less than 1 p.p.m. P_2O_5 remained in the supernatant liquor. The pH values dropped in relation to the amounts of P_2O_5 remaining in solution (Figure 7), definitely showing the importance of the pH factor. It appears, therefore, that the greater is the quantity of P_2O_5 present, which can be removed by lime, the larger the floc formed; that the more P_2O_5 is present the smaller the quantity of lime needed to cause good floc formation.

Effect of $Ca(HCO_3)_2$ and CO_2

A solution containing 645 p.p.m. total alkalinity and 130 p.p.m. acidity, obtained by bubbling CO_2 through distilled water containing marble chips, was added together with sufficient K_2HPO_4 to have a resultant alkalinity and acidity equivalent to that found in domestic sewage. Lime as a saturated solution was then added and the mixture flocculated and settled.

Typical results obtained are shown in Table IV. It is evident that in general P_2O_5 removal and the resultant pH values were not materially changed by the alkalinity and acidity, but the precipitation of P_2O_5 was not so complete up to 50 p.p.m. CaO. Optimum floc formation occurred when the bicarbonate disappeared, but there seemed to be no relation between the amounts of carbonates present and the floc formed. The larger sized floc appeared when the total alkalinity was lowest and before hydroxide alkalinity was present.

Solubility of Calcium Phosphates

$CaHPO_4 \cdot 2H_2O$, $Ca(H_2PO_4)_2 \cdot H_2O$ and $Ca_3(PO_4)_2$ were stirred in distilled water for ½ hour, the suspension was filtered, and the phosphate was determined in the filtrate. All three salts gave solutions which contained more

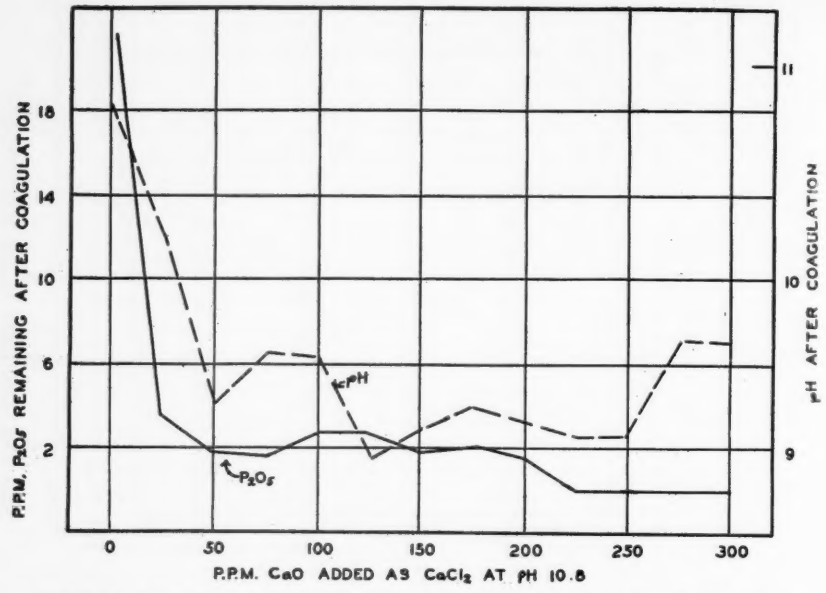

FIGURE 7.—Relation between phosphate remaining in solution and pH values.

phosphate than remained in solution (50 to 100 p.p.m.) after treatment of the potassium and sodium phosphates with lime, indicating that considerable quantities of phosphate can be in solution as calcium salts. The phosphate precipitate formed by the addition of lime to sewage may be a complex substance such as calcium-sodium (potassium) phosphate.

Removal of Phosphates from Sewage by Coagulation

On the basis of the relation between phosphates in sewage and the degree of suspended solids removal by coagulation, it is evident that phosphates are removed from the sewage and deposited in the sludge. This is further borne out by the fact that both chemi-

TABLE IV.—Effect of $Ca(HCO_3)_2$ and CO_2 on Precipitation of K_2HPO_4 with Lime

CaO (p.p.m.)	P_2O_5 After Coag. (p.p.m.)	pH After Coag.	Acidity (p.p.m.)	HCO_3^- (p.p.m.)	CO_3^- (p.p.m.)	OH^- (p.p.m.)	Total Alkalinity (p.p.m.)	Floc
0	20.2	7.18	31	205	0	0	205	none
25	5.69	8.11	0	215	16	0	231	fluffy
50	1.50	8.78	0	193	52	0	245	more granular
75	0.66	9.12	0	127	66	0	193	more granular and larger
100	0.68	9.28	0	97	76	0	173	more granular and larger
125	0.62	9.67	0	47	100	0	147	more granular and larger
150	0.95	9.94	0	16	114	0	130	appr. 2–3 mm.
175	0.74	10.01	0	10	130	0	140	appr. 2–3 mm.
200	0.76	10.65	0	0	122	59	181	appr. 2–3 mm.
225	0.90	10.85	0	0	120	81	201	appr. 2–3 mm.
250	0.76	10.98	0	0	122	93	215	appr. 2–3 mm.
275	0.70	11.15	0	0	102	148	250	appr. 2–3 mm.
300	0.85	11.28	0	0	84	207	291	appr. 2–3 mm.

TABLE V.—Average Volatile Matter and Phosphoric Acid Contents of Various Types of Sludges

Type of Sludge	Volatile Matter (%)	Phosphoric Acid		
		Total (%)	Insoluble (%)	Available (%)
Raw, Settled	74	1.49	0.22	1.27
Settled and Digested	42	1.88	0.31	1.57
Humus Tank	57	3.49	0.58	2.91
Activated Sludge	81	3.25	0.32	2.93
Fresh Chemical	66	3.14	0.35	2.79
Digested Chemical	47	4.59	0.36	4.23
Mixed Fresh and Activated	77	1.98	0.26	1.72
Digested Mixed Fresh and Activated	53	1.92	0.36	1.56
Digested Mixed Fresh and Humus Tank	52	2.27	0.61	1.66
Fresh Filter Cake	58	1.60	0.22	1.40
Digested Filter Cake	56	1.48	0.29	1.19
Digested Chemical Filter Cake	34	2.50	0.25	2.25

cally and biologically coagulated sewage sludges contain appreciably greater quantities of phosphoric acid than does plain settled sludge (2). The variation of phosphoric acid present in various sludges is illustrated in Table V.

To determine more specifically the removal of phosphates and the effects of different types of phosphates on the degree of phosphate removal, a series of experiments were made with addition of various amounts and types of phosphates added to sewage. To precipitate the phosphates the sewage was treated with various amounts of lime. An example of the results obtained is shown in Table VI. Phosphates were added in this case in the form of KH_2PO_4, lime was added, the sewage stirred for 15 minutes, settled for 30 minutes and the P_2O_5 remaining in the supernatant determined. It can be seen that over 90 per cent of the P_2O_5 was removed with 25 p.p.m. CaO and about 98.5 per cent with 50 p.p.m. CaO at a pH value of 10.5.

TABLE VI.—Removal of P_2O_5 by Hydrated Lime

CaO Added (p.p.m.)	P_2O_5 Remaining (p.p.m.)	pH
0	20.10	6.70
25	1.59	9.61
50	0.30	10.53
75	0.46	10.83
100	0.31	10.98
125	0.51	11.11

Removal of Phosphate From Supernatant Liquor

Coagulation of sewage results in the transference of phosphates to the sludge. During anaerobic decomposition a portion of the sludge is dispersed in the supernatant liquor, resulting in an increase of phosphoric acid in the liquor. Although the question of the effect of phosphates on the removal of suspended solids present in supernatant liquor will be discussed in more detail in a subsequent paper, an example of P_2O_5 removal by lime slurry is shown in Table VII. In this case the turbidity of the supernatant was low, amounting to 670 p.p.m. in the untreated liquor, in an effort to come as close to raw sewage as possible. The supernatant was flash mixed and allowed to settle for one hour. Purposely, insufficient lime was added to complete clarification. The amount of P_2O_5 in the

TABLE VII.—Removal of P_2O_5 from Supernatant Digester Liquor by Lime Slurry

CaO Added (p.p.m.)	pH of Effluent	O.C. Removed (%)	Turbidity Removed (%)	Increase in P_2O_5 of Sludge (%)	Sludge Volume (%)
0	7.30	0	0	0	1.9
200	7.49	12.9	2.0	9.5	2.0
400	7.60	15.4	8.6	13.5	2.6
600	7.78	18.4	10.6	17.5	2.9
800	7.89	23.6	15.5	20.0	3.7
1,000	7.97	27.8	19.0	23.0	4.1

untreated material amounted to 24.2 p.p.m. To obtain complete clarification with lime the pH values must be raised to approximately 10.5. No such increase in pH values was made with the particular liquor under discussion; hence, the degree of turbidity removal was relatively small. The results show that the P_2O_5 content of the sludge increased with increasing quantities of lime added, paralleling the percentage turbidity removal. The removal of P_2O_5 from the liquor with increasing quantities of lime is illustrated in Figure 8. Of interest are the percentages of removal of oxygen consuming matter in relation to the percentages of increase in P_2O_5 in the sludge.

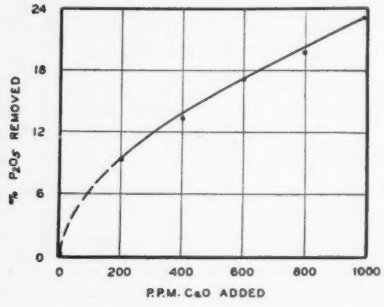

FIGURE 8.

Effect of Phosphates on Sludge Volume

Results presented in Table II show an increase in sludge volume with the addition of disodium phosphate when lime is used for clarification. The volume of sludge increases with increasing quantities of lime. The increase in sludge volume is not the result of the increasing quantities of lime added, although additional amounts of lime do increase the weight of the sludge. The increasing volume of sludge with increasing quantities of lime is illustrated in Table I, where the results obtained on sewage with and without urine addition are given.

It appears that the type of phosphate added affects the sludge volume. Apparently, some phosphates have little, if any effect, others may reduce the sludge volume, whereas still others may increase the sludge volume to varying degrees. This is illustrated in Table

TABLE VIII.—Changes in Sludge Volume Produced from Strong Sewage Treated with Different Phosphates *

Settling Time	$Ca(H_2PO_4)\cdot H_2O$	$(NH_4)_2HPO_4$	$Na_2HPO_4\cdot 12H_2O$	H_3PO_4
5	0	−14	+40	+40
10	0	−10	+12	+13
30	0	−10	+10	+10
60	0	−10	+ 7	+ 8
120	+10	−10	+ 3	+ 6

* 5 p.p.m. PO_4 added in all cases.

VIII, where the percentages of change in sludge volume, as compared with untreated sewage, are presented for different phosphates. The calcium monophosphate showed some increase after 2 hours' settling, whereas ammonium phosphate showed a decrease in sludge volume. The disodium phosphate and phosphoric acid showed a slight increase with 5 p.p.m. PO_4 additions. It is evident that sludge formation was greatest during the first 5 minutes of settling, decreasing with increased settling time. This "immediate" increase seems to indicate that these phosphates aid floc formation and may be a factor in sludge dewatering.

Discussion

Phosphates present in sewage are readily precipitated with calcium hydrate, as evidenced by the increase of phosphate content of the sludge and the reduction of phosphate in the supernatant liquor. The bulk of the phosphates are rapidly precipitated and a floc is formed. This floc continues to grow until at about pH 10 a large floc begins to form which reaches its maximum size at about pH 10.8. The work indicates that the phosphates can remain in solution combined with calcium, probably as a complex phosphate. The removal of phosphates from solution is not materially affected by bicarbonates or carbon dioxide present, but the action of lime is slower and less complete with smaller quantities of lime. Optimum floc formation occurs when bicarbonates disappear.

In sewage clarification with lime alone clarification proceeds gradually until a pH of about 9.5 is reached, but increased clarification occurs in a pH range of 10.4 to 10.8. Phosphates cause a shift downward of the optimum pH values. Coagulation at the optimum pH value is accompanied by a sudden increase in clarification. This increase is illustrated by two examples in Table IX. There is no relation between this increase in clarification and the gradual reduction of carbonates present. The sharp increase in clarification occurs within narrow limits of lime addition and pH change. This checks with numerous plant operation observations, which show that floc formation proceeds gradually and, when a certain pH is reached, clarification is nearly instantaneous.

Coagulation begins when about 70 to 80 per cent of the phosphates present are precipitated, and larger floc is usually formed when less than 1 p.p.m. P_2O_5 is left in solution. When iron salts are used for sewage coagulation, increased quantities of phosphates require larger amounts of iron salt, but when lime is used, larger quantities of phosphates require less lime.

TABLE IX.—Relation Between Alkalinity and Sewage Clarification

CaO Added (p.p.m.)	Turbidity (p.p.m.)	Turbidity Removal (%)	pH Effluent	HCO_3^- (p.p.m.)	$CO_3^=$ (p.p.m.)	OH^- (p.p.m.)
0	210	0	7.88	393	0	0
200	132	37	9.16	45	484	0
300	86	59	9.52	0	432	36
400	88	58	10.43	0	312	191
500	<15	>93	11.11	0	232	387
600	clear	>98	11.31	0	210	395
0	204	0	7.59	380	0	0
400	75	63	9.55	0	288	103
425	75	63	10.32	0	238	184
450	15	93	10.90	0	210	289
475	<10	>95	11.00	0	210	278

In practice this means that the more urine present the greater the quantity of iron salt and the smaller the amounts of lime required to produce good clarification. The increased quantities of iron salt and decreased amounts of lime can also be correlated with the quantities of ammonia nitrogen present, the NH_3–N serving as an index of the quantities of urine present.

The role of phosphates in sewage coagulation may be summarized as follows: Calcium precipitates the phosphates, forming a series of calcium-sodium (potassium) phosphates with complex structures. These complexes, distributed throughout the liquor, can remain in solution, but during the formation of the lattice structure other ions and suspended materials are adsorbed. The floc formed increases in size with increased phosphate precipitation.

Various factors affect the rate and size of floc formation as well as the speed and completeness of phosphate precipitation, hence, the rate and degree of clarification are affected by the same factors.

Small additions of phosphates do not affect the rate of settling of sewage to a measurable degree, but certain phosphates cause an increase in sludge volume. These phosphates produce a sludge which contains more water. The phosphates which have the greatest effect are those normally present in sewage (disodium phosphate, monosodium phosphate and phosphoric acid). Trade wastes which contain certain types of phosphates (particularly animal wastes, spent broth from fermentation processes, etc.), and which are present in sewage, produce voluminous quantities of sludge when treated with coagulants.

Summary

In sewage coagulation calcium carbonate has been held responsible for clarification. Experimental work has shown that 95 per cent of the turbidity is removed in sewage coagulation before calcium is precipitated from solution.

High urine contents of sewage cause increased iron salt demand for effective coagulation, but less lime demand. Phosphates, present in urine, were found to be responsible.

Phosphates in sewage are readily precipitated by lime, probably forming complex substances. Floc formation begins with phosphate precipitation, and a large floc begins to form at pH 10.1, reaching a maximum at pH 10.8. Phosphate removal from solution is not materially affected by bicarbonates and carbon dioxide. Carbonates decrease with increased clarification.

Several factors affect the rate and size of floc formation and may cause a shift in optimum pH for maximum clarification. It is believed that the lattice structure of the calcium-sodium (potassium) phosphates adsorb other ions and suspended materials.

The phosphates removed from the sewage are precipitated in the sludge formed, hence, the P_2O_5 content of chemically or biologically precipitated sludge is higher than in plain settled sludge. Small additions of phosphates (5 to 10 p.p.m.) do not affect the degree or rate of clarification of untreated sewage, but volumes of sludge produced are larger.

The phosphates normally present in sewage (disodium phosphate, monosodium phosphate and phosphoric acid) have the greatest effect on coagulation, clarification and settling.

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SEWER PIPE JOINTING RESEARCH—A PROGRESS REPORT *

By Harvey W. House and Richard Pomeroy

Everyone will agree that among the things a sewer pipe joint is supposed to do is to keep the rain and roots out and the sewage in. And it appears to follow from the nature of roots that if a joint is strong enough—one might almost say intelligent enough—to keep the roots out, the other purposes will be automatically achieved.

Roots have been known to crawl unbelievable distances through the most devious channels to get at the water inside of pipes. The story is told, for instance, of a root in one yard that grappled with a threaded water pipe, and by a process of muscular action wore a hole down to the water. In another case a sycamore tree is alleged to have observed water in the sewer pipes of a neighbor's yard, and sent its roots under an intervening dry wash and through 50 ft. of abandoned pipe, finally to bore through a plastic joint and proceed up to the kitchen sink.

The clay pipe industry, no doubt moved by these experiences, has for many years been endeavoring to improve the jointing of its pipe, and thus to make the joints equal the pipe in resistance to root penetration and related failures.

Current Research

In January, 1945 the Pacific Coast Clay Products Institute started a research project on this problem with Dr. Richard Pomeroy as advisor. The laboratory of Gladding, McBean and Company at Glendale was selected as the central location for the work. During the first five months of the investigations, Mr. Artis Maldonado was loaned by the Pacific Clay Products Company to work on a part-time basis on the various experimental tests. In June, the senior author was secured for full-time work on the project.

The scope of the investigation has involved the study of all types of joints, including bell-and-spigot, collar, push-together, and miscellaneous other proposed types; and an investigation of all sorts of jointing materials, such as cold-setting cements, sulfur-base mixtures, elastomers, and bituminous or resinous materials. This present report deals only with the research on jointing materials to fill bell-and-spigot or collar type joints.

Common Jointing Materials

In the early months, considerable attention was given to cold-setting cements, including quick-setting varieties and expanding cements, as well as ordinary portland cement mortar. Without going into detail, it may be said that cements of these types doubtless have an appropriate field of usefulness, especially in jointing the larger sewers, and that they will make tight joints if carefully caulked into place. For smaller sizes, however, where inspection is generally inadequate, careless workmanship has frequently resulted in joints which were not tight. Furthermore, the joints are rigid, causing breakage of the pipe if there is very much soil movement.

Sulfur-base compounds have, of course, been widely used, but have the disadvantage of rigidity. Observation has also now revealed that these joints may fail within a few years, due to action of soil and sewage bacteria upon the sulfur. No way has yet been found to overcome these weaknesses.

* Presented at 1946 Annual Convention of the California Sewage Works Assn., Monterey, Calif., June 10–11, 1946.

Hot-poured bituminous or resinous compounds seemed at first to have just as many drawbacks as the other types of materials. They do provide flexible joints, but complaints of root penetration in house connections and sewers have been even more numerous (proportionally) than with cement mortar joints. It had been established in root-plot tests that, under conditions favorable for root growth, joints made with common asphalts are likely to fail in six months. A relatively hard, widely-used, asphaltic, jointing material has failed within nine months, and a widely-used, cumarone-indene resin preparation has shown root penetrations in 18 months, and also has shown evidence of physical deterioration, due to water absorption.

Causes of Failure

In some cases, these penetrations by roots could be traced to bubbles or blow-holes in the jointing material. Sometimes it was due to cracks. In other cases it appeared to be due to separation of the material from the clay. And then there was at least the possibility that roots might push their way right through the body of the jointing material.

Taking up these problems one at a time, a little study showed that blow-holes are not a serious problem. They are limited to a few poorly compounded materials, or to preparations which have been seriously overheated or to extreme carelessness in workmanship. Cracks in the body of material can also be avoided, because they appear only in excessively brittle preparations. But what about the separation of the compound from the pipe surfaces. Could anything be done about this very common cause of failure?

Adhesion

A few preliminary tests showed that the strength of the bond formed between a bituminous material and a clay surface is dependent upon the properties of the material, the conditions of pouring, and the condition of the clay surface. For example, it was found that a small patch of compound poured onto a pipe might stick while dry, but would come off later if soaked in water. But it was also found that if the compound was poured in a thick layer, so that high temperature was maintained over a period of several minutes, adhesion would remain, in the case of some compounds, even after soaking.

Another important finding was that salt glazing is highly inimical to adhesion. Some materials stick very well to plain vitrified clay or ceramic glazes, but the authors have found none that will stick to clay which has been salt-glazed. Since the practice of salt glazing has nothing to recommend it and is already known to be undesirable for various other reasons, this additional indictment of it should cause no regrets.

Adhesion Test

The need for quantitative measurement of adhesion led to the development of a standard adhesion test. In this test, two 1-in. cubes of unglazed sewer pipe material were placed ½ in. apart, and the compound poured into the intervening space. The assembly was cooled, soaked for 24 hours in water and then pulled apart.

With some materials, the blocks were easily pulled apart with the fingers. With others, the breaking strength of the joint might reach 25 or 50 p.s.i. With still others the compound did not separate from the clay at all, but the break occurred only through the body of the compound itself. Fairly hard materials of this class withstood pulls ranging from 200 to 500 p.s.i. Furthermore, in these latter cases the adhesive bond showed no sign of weakening with age, at least up to several months, and separation between compound and clay did not occur in bell-and-spigot joints subjected to forces

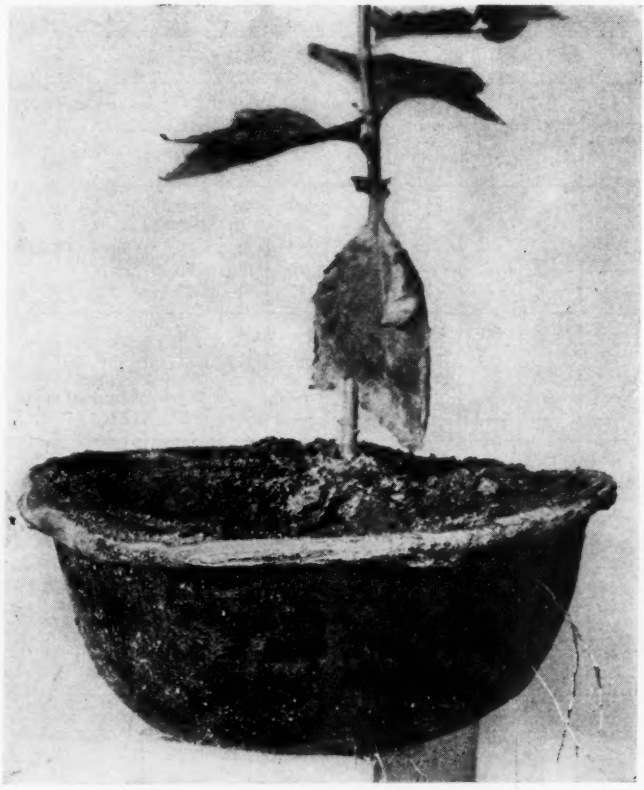

FIGURE 1.—Root penetration through 1/16-in. thickness of asphalt base jointing compound.

causing repeated back and forth bending. It seemed that materials passing such tests should be secured against failure due to interfacial separation.

Root Resistance

While these explorations of adhesion were going on, tests were also set up to answer the much discussed question as to whether roots will push through a flawless body of resinous material. Thin, basin-shaped forms of bituminous materials were molded, set in the ground, filled with soil, and planted with suitable small trees. The unequivocal answer afforded by these tests is clear from Figure 1. The basins were punctured by roots in numerous places.

It was now evident that an extensive series of tests would be necessary to find if there are any compounds able to resist this sort of penetration, and to find what factors were important in such resistance.

Root Penetration Test

A standard root penetration test was devised, which consisted of the use of pots made with 6-in. lengths of unglazed 4-in. pipe stock. To prepare such a pot, a pipe section was stood on end on a piece of cellophane and the melted compound poured in to make a layer ¼ in. thick. When cool, the cellophane was pulled off, leaving a

TABLE I.—Test Data on Sewer Jointing Compounds

Comp. No.	Composition of Compound (Exclusive of Filler)—Per Cent										
	Ester Gum	Limed Rosin	Gilsonite	220° Coal Tar	Coating Asphalt	Saturant Asphalt	Coumarone Resin	Hercolyn	Creosote	Other Components	
										Name	Per Cent
1	—	—	—	—	—	—	59	38	2.5	—	—
2	—	—	—	—	—	—	60	40	—	—	—
3	—	—	—	—	—	—	60	39	—	Copper Oleate	1.0
4	—	—	—	—	—	—	70	20	10	—	—
5	—	—	—	—	75	—	15	—	10	—	—
6	—	—	—	60	—	—	—	40	—	—	—
7	—	—	—	—	75	—	20	—	5	—	—
8	—	—	—	—	50	49	—	—	—	Copper Oleate	0.5
9	—	—	—	—	47	48	—	—	—	Copper Oleate	5.0
10	—	—	—	—	—	—	—	—	17	G.K.	83
11	—	—	19	—	—	77	—	—	—	Zinc Stearate	4.0
12	—	—	19	—	—	77	—	—	—	Aluminum Stearate	4.0
13	—	—	—	—	—	—	—	15	—	Bitumastic No. 1	85
14	—	—	19	—	—	77	—	—	—	Calcium Stearate	4.0
15	—	—	—	—	50	—	50	—	—	—	—
16	—	—	75	—	—	—	—	—	25	—	—
17	—	—	—	—	75	—	25	—	—	—	—
18	—	—	—	50	—	50	—	—	—	—	—
19	25	50	—	—	—	—	—	—	25	—	—
20	85	—	—	—	—	—	—	—	15	—	—
21	—	—	—	—	—	—	—	—	—	G.K.	100
22	—	10	—	—	90	—	—	—	—	—	—
23	—	—	—	—	100	—	—	—	—	—	—
24	75	—	—	—	—	—	—	25	—	—	—
25	—	—	—	75	—	—	—	25	—	—	—
26	—	15	—	—	85	—	—	—	—	—	—
27	—	20	—	—	80	—	—	—	—	—	—
28	—	—	—	50	50	—	—	—	—	—	—
29	—	25	—	—	75	—	—	—	—	—	—
30	—	—	—	—	—	—	60	40	—	—	—
31	—	—	—	85	—	—	—	15	—	—	—
32	—	—	25	—	75	—	—	—	—	—	—
33	—	—	—	—	—	—	—	—	—	Bitumastic No. 1	100
34	—	—	75	—	—	—	—	—	—	Flexalyn	25
35	—	—	85	—	—	—	—	—	15	—	—
36	—	—	50	—	50	—	—	—	—	—	—
37	—	—	—	—	—	—	—	—	—	CPA—111	100
38	85	—	—	—	—	—	—	15	—	—	—
39	—	—	85	—	—	—	—	—	—	Abalyn	15
40	—	—	75	—	25	—	—	—	—	—	—
41	—	85	—	—	—	—	—	15	—	—	—
42	—	—	—	75	—	25	—	—	—	—	—
43	—	75	—	—	—	—	—	25	—	—	—
44	—	—	—	—	—	83	17	—	—	—	—
45	—	85	—	—	—	—	—	—	15	—	—

TABLE I (Cont.)—Test Data on Sewer Jointing Compounds

Comp. No.	Water Absorption (%)	Adhesion (p.s.i.)	Penetration (Hardness)				Root Penetration[1]		
			By ¼-Inch Rod (mm./day)			ASTM Penetrometer—15 Sec.; 250 Gm. (tenths of mm.)	30 Days (through)	88 Days (through)	88 Days (started)
			250 Gm.	1,600 Gm.	7,750 Gm.				
1	6.7	[2]	73,000	—	—	—	X	—	—
2	1.0	[2]	55,000	—	—	—	X	—	—
3	3.0	[2]	37,000	—	—	—	—	X	—
4	1.1	[2]	24,000	—	—	—	X	—	—
5	0.3	[2]	17,000	—	—	—	X	—	—
6	0.4	[2]	7,300	—	—	—	X	—	—
7	0.6	[2]	7.000	—	—	—	X	—	—
8	1.9	[2]	5,500	—	—	—	X	—	—
9	1.0	[2]	4,400	—	—	—	—	—	X
10	—	[2]	4,000	—	—	—	—	—	—
11	—	[2]	3,400	37,000	—	—	X	—	—
12	—	[2]	2,600	28,000	—	—	X	—	—
13	0.2	[2]	2,300	16,000	—	—	X	—	—
14	—	[2]	1,500	20,000	—	—	X	—	—
15	0.8	[2]	1,400	55,000	—	—	—	X	—
16	0.0	0	640	17,000	—	—	—	—	X
17	0.6	90	150	7,900	—	—	X	—	—
18	0.1	60	110	22,000	—	—	—	X	—
19	1.6	146	—	2,100	—	84	—	—	—
20	0.4	145	—	2,100	—	66	—	X	—
21	—	77	—	1,600	—	118	—	X	—
22	1.0	118	9	528	44,000	71	—	—	X
23	0.7	85	—	528	66,000	88	—	X	—
24	0.6	156	—	370	—	17	—	X	—
25	0.2	270	—	350	—	50	—	X	—
26	1.1	46	—	310	22,000	75	—	—	X
27	1.1	0	—	242	—	50	—	X	—
28	0.5	157	—	220	—	57	—	—	X
29	0.9	100	—	220	—	65	—	—	X
30	0.9	220	—	190	—	12	—	—	X
31	0.2	398	—	79	—	28	—	—	X
32	0.6	134	—	33	4,200	—	—	—	X
33	—	431	—	—	630	19	—	X	—
34	0.2	78	—	—	150	7	—	—	X
35	0.0	55	—	—	120	9	—	—	—
36	0.6	63	—	—	70	18	—	—	—
37	—	135	—	—	55	2	—	—	—
38	0.3	172	—	—	44	1	—	—	—
39	0.1	65	—	—	16	1	—	—	—
40	0.3	47	—	—	4	3	—	C	—
41	0.3	0	—	—	3	1	—	C	—
42	0.1	127	—	—	1	16	—	—	—
43	0.9	0	—	—	1	0	—	C	—
44	0.3	0	—	—	0	0	—	C	—
45	0.5	0	—	—	0	0	C	—	—

[1] X denotes penetration by roots; C denotes penetration through cracks.
[2] Joint elongated but not broken.

round pot with a flat bottom of the compound to be tested.

A seedling of eucalyptus or privet was planted in soil inside the pot, and the whole thing set in a sand box, jacketed on the sides and bottom with circulating water at 80° F. In Southern California, the sewage temperatures generally range from about 65° F. in the winter to 75° F. in the summer. The use of a temperature of 80° in the tests assured good root growth, even in the winter, and also caused the compounds to be somewhat softer than they would be under the usual conditions of use, even in this warm climate. Thus the tests favored more rapid penetration than would be expected in normal application.

The first large-scale series using this procedure was started in October, 1945, with 90 pots, testing in duplicate 45 different resinous or bituminous mixtures.

FIGURE 2.—Root penetration through ¼-in. layer of asphalt base jointing compound (side view).

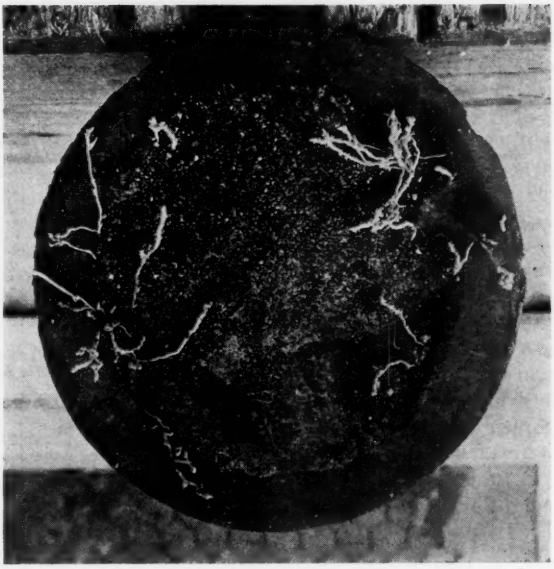

FIGURE 3.—Root penetration through ¼-in. layer of asphalt base jointing compound (bottom view).

Results of Tests

A summary of the data relative to this series is presented in Table I, in which the materials are arranged in order of increasing hardness. It is seen that a group at the top of the list (very soft compounds) was penetrated within one month. During the next two months roots came through an additional group of somewhat harder compounds. Also, a group of very hard materials at the end of the list showed roots coming through cracks which probably had formed soon after pouring. But at the end of three months, a group of eighteen compounds, mostly in the lower half of the list, showed no roots coming through. At this time, most of these remaining pots were broken for careful examination.

It was found that in ten of the compounds, mostly the softer ones, the roots were well started, indicating that it would have been only a few weeks or months until they too would have penetrated the compounds. Of the eight still intact, six were near the very hard end of the scale, and two were softer compounds of high creosote content. Figures 2 and 3 show penetration of privet through a commercial asphalt base compound in one of these standard pots.

It appeared that hardness is a major factor in determining root resistance. Yet it was found that hardness alone is not sufficient, even when there is no cracking, for when a few of the pots containing these hard materials were kept in the sand plot for seven months, an interfacial type of failure occurred, in which roots pried the compound away from the clay surface. This was true in the case of the materials listed as Nos. 35, 36, and 37 in Table 1, and doubtless is related to the fact that these compounds had relatively poor adhesion in comparison with their hardness. In the adhesion tests they separate at the interface instead of breaking through the compound. Compounds which are still harder than

these may keep the roots out even if adhesion is poor, but they are dangerously brittle.

Thus the ideal material would seem to be one which has high adhesion and is at the same time too hard for the roots to penetrate, but not hard enough to crack on cooling. Toxicity might seem to be a significant factor, in view of the fact that two compounds of high cresosote content were resistant, at least for three months (Nos. 10 and 19). It does not appear, however, that reliance can be placed on toxicity, for other specimens containing creosote in amounts from 10 to 25 per cent of binder, or copper oleate up to 5 per cent, caused only moderate retardation (Nos. 5, 6, 9, 16 and 20).

Actually, none of the 45 compounds tested seemed to fulfill the requirements of an ideal material, but the series showed what was required. It was evident, in the first place, that an adhesion of 200 p.s.i. was both attainable and necessary. It was equally clear that a certain range of hardness was essential. But the specification of this hardness was by no means simple, due to the complexity of this property.

Tests which depend upon a rate of deformation under a specified stress cannot be correlated when the stress conditions are changed. This is evident from Table I, showing penetrations by a ⅛-in. diameter rod under different loads. The deformations are not in the same order under these different loads.

Hardness Studies

A more detailed examination of this phenomenon was carried out in the case of two materials, with the results shown in Figure 4. At a load of 2,100 grams (on a 1-mm. diameter rod) an asphalt-gilsonite compound was penetrated twice as fast as a coumarone-indene resin compound, but at a load of 60 grams the latter was penetrated three times as fast as the former. The

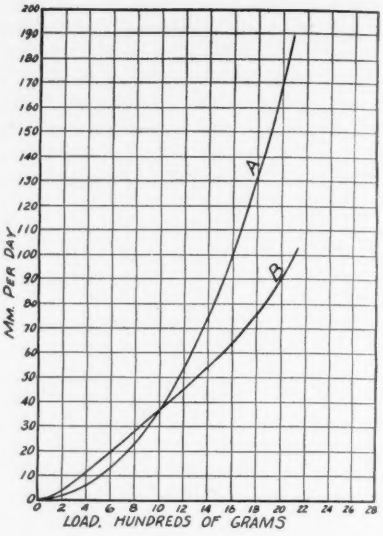

FIGURE 4.—Effect of load upon rates of penetration of asphalt-gilsonite (A) and coumarone-indene (B) jointing compounds.

higher load therefore gives a totally misleading evaluation of the relative hardness of the two materials under lower loads. The standard ASTM penetrometer test imposes a stress much greater than even the maximum stress used in these tests.

Test Procedure

Ideally, the hardness should be measured with stresses comparable to those which effect root penetration in the harder materials, but this would require testing over a long period of time to get measurable motion. A practical compromise has been necessary.

The test which has been tentatively chosen as standard, hereafter referred to as the CPI method, calls for measurement of the penetration in 24 hours at 25° C. by a flat-ended rod 1 mm. in diameter, weighted so as to press into the surface of the compound with a force of 60 grams. It is further required that the test be started within one hour after the time of melting and

pouring the sample, since hardness changes with age.

The preliminary observations up to and including the 90-pot test series indicated that a suitable compound would show a CPI penetration of the order of magnitude of 0.1 to 1.0 mm. Further investigations were therefore undertaken to determine what general classes of materials would be suitable to meet the requirements of adhesion and hardness, and to explore in greater detail the proper hardness range.

The preparations which have been tested, including the 45 listed in Table I, have covered all available proprietary compounds, as well as mixtures based upon asphalts and other mineral resins, coal tars, natural resins and rosin esters, coumarone-indene and synthetic resins, and various mixtures of these among themselves and with other modifying agents. The only compounds found thus far which meet the requirements of adhesion, hardness and strength, as well as stability, are certain properly made coal-tar preparations. Specifically, a suitable coal-tar pitch, mixed with a mineral filler such as powdered silica in the proportion of three parts by weight of tar to one of filler, may provide a preparation coming within the desired range of properties. The further work on hardness ranges was then limited to preparations within the coal-tar class.

Effect of Temperature

In these investigations temperature is a major factor. To gain an accurate knowledge of the effect of this temperature factor upon the hardness, measurements of penetration by the standard CPI method (60 gm., 1-mm. rod, 24 hours) were taken at temperatures ranging from 70° to 90° F. These all revealed a temperature susceptibility such that each degree change in temperature caused a change in penetration of 20 per cent. An increase in temperature of 10° F. multiplies the rate of penetration (CPI method) by almost seven times.

The bearing of this temperature effect upon vulnerability to roots has been shown by a number of tests made with an experimental compound having a CPI penetration of 0.4 mm. (at 77° F.), and an adhesion of over 200 p.s.i. Twenty test pots of this compound were set out, half in the 80° controlled temperature plot on the sunny south side of the laboratory building, and half in the shaded, weather-temperature plot on the north side. These pots were set out on April 23, 1946. On July 30, 98 days later, several pots were dug up in various locations, with the following results:

1. On the exposed, southern edge of the "controlled temperature" plot, although temperatures were held to a minimum of 80° F., the summer sun exposure had permitted the temperature to go up to 89° F. during the day. Pots at this location showed complete penetration.

2. In the middle zone, where temperatures had reached only 83°, penetration of the order of ⅛ in. was noted.

3. On the north side, in shaded, unheated pots, where temperatures did not go above 76°, no penetration was observed even though roots packed themselves densely at the critical interfacial line between compound and clay.

In addition to the above evidence showing the effect of temperature, a test with actual joints was made. Three joints made with a coal-tar silica mixture having a penetration value of 0.8 mm. were set out near eucalyptus roots and kept filled with water. Nine months later (time interval, September, 1945 to June, 1946) these were dug up, and although the joints were heavily matted with roots, there was no beginning of penetration. During this test the temperature was not observed, but it is to be noted that the

joints were in shaded soil, and the experiment was conducted mostly during the winter months.

There is an upper limit to the hardness which can be specified, conditioned by the tendency of very hard materials to crack when temperature is rapidly lowered. A joint made with compound having a CPI penetration of 0.4 mm., for instance, cracked at 43° F. when cooled from 70° to the cracking temperature in 40 minutes. Another similar joint, cooled from 60°, cracked at 40 degrees when the cooling took place uniformly over a period of 100 minutes.

Discussion of Hardness Test Results

It is clear from these data that the proper hardness for jointing material of this type will depend upon the conditions of use. In locations where soil temperatures are at the level usually encountered in Southern California, and where roots are a menace, a quite hard compound should be specified. It is the tentative opinion of the authors that satisfactory results may generally be expected in these situations if the CPI penetration of the compound as delivered is held within the limits of 0.1 and 0.5 mm.

It should be noted in this connection that the hardness will increase when the compound is used in the field, presumably by loss of volatiles. For instance, in the installation of a test line at Long Beach, Calif., a coal-tar compound was used which had a CPI penetration of 0.4 mm. at the beginning of the run. This quickly fell to 0.2 mm., where it remained until the end of the run, being kept approximately constant by the addition of new compound to the kettle. Thus, if the compound as purchased has a CPI penetration not greater than 0.5 mm., when it is poured into the joints it will have a penetration materially less than this, and should stop roots under all ordinary conditions.

There are probably some locations where even harder jointing material is necessary, particularly in climates where summer temperatures rise considerably higher than is general in most of California. On the other hand, it is often permissible even in hot climates to use softer materials, as in locations where roots are absent, or where ground water is high. In these cases the penetration may be between 0.5 and 5.0 mm.

In cooler climates the softer compounds are necessary as a safeguard against cracking when lines are poured in the winter. In such climates soil temperatures even in summer are also likely to be much lower. It is estimated that CPI penetration in such cases might be specified as high as 10 mm. These statements must be taken

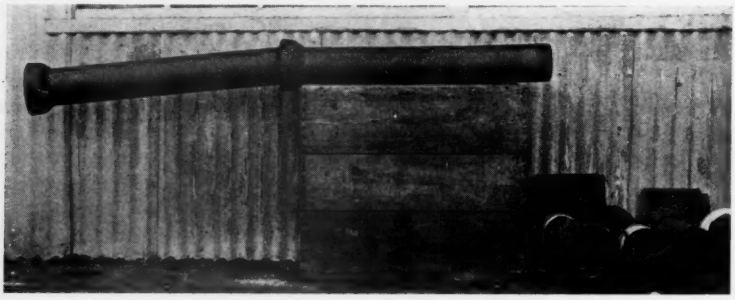

FIGURE 5.—Pipes (originally straight) joined with hard coal-tar compound, after bending moment of 120 ft.-lb. applied for 3 days, in a water tank maintained at about 70°F.

TABLE II.—Scoring of Five Major Types of Jointing Compounds

	Portland Cement	Sulfur-Silica	Asphalt	Coumarone Indene	Coal Tar as Specified
Yields to Avoid Breakage of Pipe	No	No	Yes	Yes	Yes
Resists Deterioration	Yes	No	Yes	No	Yes
Resists Roots	Yes	Yes	No	No	Yes
Is Easily Made Well	No	Yes	Yes	Yes	Yes

as qualitative, for the more accurate specification of limits of hardness must await further research.

A compound hard enough to resist root growth under adverse conditions, *i.e.*, with CPI penetration less than 0.5 mm., is very hard indeed. Yet a joint between two 3-ft. lengths of 4-in. pipe under a bending moment of 40 lb. at 3 ft. (120 ft.-lb.) bent about 3 in. in three days at approximately 70° F. (Figure 5). Thus the compound yields in response to very moderate bending stress, so that breaking strains are unlikely to develop. These tests have also shown that under this punishment the joints remain tight.

Reference has already been made to the testing of a coal-tar having a CPI penetration of 0.8 mm., under approximate field conditions. A similar compound having a CPI penetration value of about 10 mm., in a similar field test, showed a root penetration of over ½ inch. Thus the laboratory evidence of both the adequacy and the necessity of the specified hardness and adhesion was supported with actual joints under approximate field conditions.

Conclusion

In spite of all these experiments, it is still true that many more laboratory and field tests must be made before the case in favor of compounds with the adhesion and hardness here described may be considered as proved. This research will therefore continue in the hope that any uncertainties which may at present exist may be cleared up.

Meanwhile, the authors believe that coal-tar jointing compounds with the adhesion here described, and with hardness chosen within the indicated ranges to correspond to the conditions of use, will provide greater assurance of satisfactory joints than is likely to be attained with any other of the widely used jointing materials.

In conclusion, Table II is presented to show the relative standing of different types of materials which have been used for sewer pipe jointing, as scored by the four major questions which may be applied to joint compounds:

1. Will the compound flow sufficiently to prevent pipe breakage due to ground movement?
2. Is it stable over many years, under joint conditions?
3. Does it resist roots, both at the interface of pipe and compound, and through the compound?
4. Will the usual work crew make all joints tight?

The answers to these questions, according to the best evidence now available to the authors, is given under the several compound-class headings, in the form of "yes" or "no" answers.

CONCENTRATION OF ACTIVATED SLUDGE *

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The concentration of activated sludge has long been a problem to designers and operators of sewage treatment plants. The designing engineers have been perplexed over sludge concentration when they were considering the capacities of return sludge pumps, secondary settling tanks, sludge digestion tanks and of the disposal facilities for sludge either before or after digestion. The plant operator has been afflicted with the operation of activated sludge plants which were in some way not able to meet the requirements placed upon them.

Travaini (1) wrote in 1932 about the problem of sludge concentration at Phoenix, Arizona. His problem was one of concentrating activated sludge before pumping it to digestion tanks. Rudolfs (2, 3, 4) has written of his experimental work in which efforts were made and logical reasons deduced for the behavior of activated sludge. In a symposium on "Concentration of Sewage Sludge" by Gowdy, Keefer, Rudolfs and Donaldson (5) they discuss their studies and observations, and give recommendations for meeting the difficulties encountered when activated sludge will not or does not concentrate sufficiently.

These authors give their readers information that has been of material help to many. There are still many difficulties experienced even today and to say that the above workers did not have the answers would be a gross injustice. The information given in this paper is offered only as an expression of opinion and a statement of experiences and beliefs. It is hoped that in some small way these views may be of some assistance to those who still experience difficulties.

Factors Influencing Concentration

The difficulties experienced in activated sludge concentration probably start with the operation of the activated sludge plant proper. Although the ensuing discussion may appear to relate primarily to the bulking problem, it is intended to develop the concept that the condition of the sludge is a fundamental influence on its concentration properties.

Activated sludge has been defined many times, yet it seems rather useless to try and describe in a few words a substance that is made up of so many complex substances and differs so widely from plant to plant. The first time the writer observed the activated sludge at Indianapolis he was amazed because it did not have that rich brown color of the activated sludge then being handled in the Milwaukee plant.

In those days there was considerable pickling liquor being discharged to the sewers in Milwaukee and practically none was being handled at the Indianapolis plant, principally because it was believed that pickling liquor has been the cause of past difficulty in plant operation. It was at that time very easy to obtain an activated sludge at Milwaukee that would concentrate to 2 per cent solids in 30 minutes. Was it the iron that aided the concentration of the Milwaukee sludge? It seems entirely possible that the iron was beneficial, but it may also be pertinent that the Milwaukee plant was not overloaded at that time.

Mathews at Gary reports that pickling liquor in the sewage in uniform

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concentrations seems to improve the activated sludge rather than injure it. But before a definite conclusion is drawn, reference to the Gary operation reports will reveal that the B.O.D. load at this plant is not excessive.

It is usual to find the sludge in the Crawfordsville, Ind., plant with a high sludge index (200 to 500) and the sludge in the Marion, Ind., plant with a sludge index always below 100 unless it be during the food canning season. The B.O.D. of the Crawfordsville sewage is rather high (200 to 400 p.p.m.); at Marion it is usually below 200 and most months it averages below 150 p.p.m. going to the aeration tanks.

The above facts assume significance to the writer in the light of his findings at Indianapolis that the degree of concentration of activated sludge could be varied by careful control of the amount of B.O.D. being removed in the activated sludge plant. The operation records at Indianapolis indicate that the concentration of activated sludge can be controlled by adjusting the load being placed upon it, this statement being valid only if a sufficient amount of oxygen was being supplied at all times.

It was not an unusual experience to have two entirely separate activated sludge plants operating on the same sewage and yet to find entirely different sludge indexes. A similar observation has been made in a study of the operating data of the Hammond, Ind. plant where Supt. C. B. Carpenter reported recently that he is able to lower the sludge index by reducing the sewage flow to one unit, and to increase the index in another by raising the flow. He has found that the changes in flow must be made in small increments and by so doing he can keep a similar sludge index in all units of his plant.

These statements indicate that the character (that is, the concentration) depends upon the degree of oxidation being given the activated sludge. The degree of oxidation depends upon the amount of organic matter (B.O.D.) being fed to the activated sludge.

The question that might next be asked is, if the sludge index is affected by loading, how does it affect the return sludge concentration? In a previously published paper by the author (8), a settling rate graph is shown for a good activated sludge and for a poor one. The good activated sludge, when settled in a cylinder, soon reaches a concentration that does not increase materially with a longer settling period. From a typical curve it is apparent that there is not a marked decrease in volume in the sludge after 30 minutes of settling. This seems to indicate that a particular sludge from a particular plant will settle to a given concentration, but can not be concentrated further unless the sludge is physically changed in some manner. There are several methods by which the sludge can be changed so that it will concentrate further; two of them will be discussed here.

The first method has to do with the further oxidation of activated sludge by more aeration. Just what further oxidation does to sludge to make it settle no one can be quite sure. It seems quite logical that the swelling of the sludge might be caused by increased numbers of organisms which have developed in their effort to utilize all of the bacterial food present. On the other hand, it seems almost as reasonable to believe that the swelling of the sludge may be due to the absorption of bacterial food into the gelatinous masses surrounding the bacteria.

It does not matter, however, which of these two theories are accepted, because there appears to be a logical explanation of the improved concentration that results from continued aeration. If the sludge expands because of increased numbers of organisms, continued aeration without the further addition of food will eventually result in a shortage of food and a consequent

death of organisms. If there is a swelling of the gelatinous masses because of the great quantity of food absorbed by them, continued aeration without the addition of food will result in a depletion of the food and a possible shrinking of the gelatinous masses.

The reports of Tapleshay (6) and Smith (7) on the chlorination of activated sludge seem to indicate that the addition of a small amount of chlorine to the return sludge may keep the bacterial counts within the limits necessary to produce a sludge which will concentrate satisfactorily. This is a second method by which the sludge is changed in physical character.

Concentration a Function of Sludge Index

So much for the theories. The plant operator is more concerned with what can be done in a practical way to solve the problem of sludge concentration in an activated sludge plant by control of the degree of oxidation. If an activated sludge is being given all of the oxygen possible it can handle only so much B.O.D. To go beyond the limit of B.O.D. loading will result in a breakdown of the process and in the production of a sludge which can not be concentrated for further disposal in sludge digestion tanks.

The concentration of sludge for disposal (waste sludge) can be controlled by adjustments in the activated sludge plant. Many times this is not a feasible method however, because the capacities of the activated sludge units may be inadequate to give an oxidized sludge that will settle to the desired concentration necessary for disposal. In the Milwaukee plant a separate unit is used to condition the waste sludge for the vacuum filters. In 1938 the average solids content of the sludge filtered was 1.50 per cent, in 1936 it was 1.16 per cent and in 1937 it was 1.26 per cent. The maximum concentration for any month during these three years was 1.65 per cent. These rather high concentrations are, it is believed, obtained by a more complete oxidation of the sludge in the conditioning units, and are certainly not obtained by merely holding the sludge in the sedimentation tanks.

The writer is quite certain that if the average sludge index for the years above were known, that the reciprocal of the sludge index times 100 would give percentage sludge concentrations approximating those given above. By this it is meant that the probable sludge index for the above years would have been approximately as follows:

Year	Waste Sludge Solids (%)	Probable Index
1936	1.16	86
1937	1.26	79
1938	1.50	66

The writer has seen waste sludge produced in the Milwaukee plant that would settle to 2 per cent solids. This is perhaps an indication of what can be done within an activated sludge plant to concentrate the waste sludge solids.

Sludge Concentration Tanks

In most cases, plant facilities are such that it is impossible to concentrate the waste sludge within the treatment works and many efforts have been made to use resettling tanks for the concentration of the waste activated sludge.

It has been the writer's experience that it is quite impractical to concentrate waste activated sludge which has a high initial sludge index unless the sludge can be held sufficiently long for aerobic decomposition to take place and thereby change the physical composition of the sludge. Travaini reported that he obtained high concentrations but was troubled by odors; this certainly indicates that decomposition of the sludge had started.

The use of chlorine in concentration tanks may serve two purposes: (1) The chlorine may be of assistance in keeping down troublesome odors; (2) Chlorine may so act upon the sludge

TABLE 1.—Operation Data on Sludge Concentration Tank at Indianapolis

Year	Days Operated	Activated Sludge (m.g.)	Concentrated Sludge (m.g.)	Waste Activated Sludge Solids (%)	Concentrated Sludge Solids (%)	Solids Treated (1,000 lb.)	Reduction in Volume (%)	Loading (gal. per sq. ft. per day)	Susp. Solids Decanted Eff. (%)
1931	255	241.65	83.22	0.50	1.53	10164.15	64.3	272	45
1932	288	310.87	64.10	0.32	1.54	8192.68	79.4	328	43
1933	47	32.13	11.62	0.37	1.09	1040.94	63.8	208	93
1934	130	159.66	57.34	0.95	2.66	1264.89	64.1	373	134
1935	245	44.81	7.16	0.31	1.96	1166.62	84.0	56	61
1936	138	23.27	4.78	0.69	2.78	1382.46	56.0	58	38
1937	187	90.74	56.29	1.04	1.69	7619	38.0	145	74

that it changes the original physical characteristics.

Indianapolis Experience

The waste sludge concentration tank at Indianapolis has 3,292 sq. ft. of surface area. In the years past it has been operated in many different ways. One of these was to pump to the tank all of the waste sludge and take the resulting sludge concentration. One other way was to pump to the concentration tank a smaller volume of sludge and thereby allow for a longer retention period. It is most difficult to analyze the data (Table 1) to determine which was the most satisfactory method because the sludges going to the concentration tank, during the years for which information is available, were all quite different.

The sludge removed from the concentration tank had lost all of those characteristics identifying it as activated sludge. The odor of the decanted effluent was always bad unless activated sludge plant effluent was being pumped to the surface of the concentration tank, thereby washing away or diluting the less desirable liquor of the concentrated sludge.

There is no question but that the Indianapolis concentration tank was of great help in reducing the volume of sludge that required disposal. The location of this unit at a prominent point near the activated sludge plant was far from being an asset from the standpoint of appearance and fragrance. It is certainly suggested that all tanks constructed for this purpose be located as far from the public eye and nose as possible, as the beneficial service rendered by such tanks is certainly not apparent to the casual observer.

Conclusions

The following conclusions are offered on the basis of the author's experience and observations concerning activated sludge concentration:

1. The concentration of activated sludge can be controlled by changes in the method of plant operation.
2. Concentrations of activated sludge suitable for immediate discharge to digestion tanks can be obtained in the activated sludge plant.
3. The reciprocal of the sludge index times 100 is the maximum sludge concentration that can be expected from control of the activated sludge plant.
4. Sludge concentration tanks will give satisfactory results if the sludge can be held in them a sufficient length of time to bring about changes in the physical characteristics of the sludge.
5. It is difficult to operate concentration tanks without odor nuisance. Consequently, they should be designed and located so that there will be no objectionable conditions.

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A CORRECTION IN THE FERTILIZER MANUAL

All holders of copies of FSWA Manual of Sewage Works Practice No. 2, *Utilization of Sewage Sludge as Fertilizer*, are asked to note an error on page 84, in the fourteenth line from the bottom. The word "not" should be deleted in this line so that the statement shall read "Chemical precipitation or intermittent sand filtration did remove *amoeba* cysts."

Attention was called to this error by Eloise B. Cram, author of the paper "The Effect of Various Treatment Processes on the Survival of Helminth Ova and Protozoan Cysts in Sewage" (THIS JOURNAL, **15**, 1119; November, 1943), which is credited as the authority for the above statement. Our apologies go forth to Miss Cram for the unfortunate oversight that resulted in the mistake.

A CRITICAL REVIEW OF THE LITERATURE OF 1946 ON SEWAGE AND WASTE TREATMENT AND STREAM POLLUTION

By W. Rudolfs, *Chairman*, H. E. Babbitt, D. E. Bloodgood, G. P. Edwards, H. A. Faber, A. L. Genter, H. Heukelekian, H. J. Miles, F. W. Mohlman, C. C. Ruchhoft, C. N. Sawyer, L. R. Setter, L. W. Van Kleeck

Committee on Research, Section A, Federation of Sewage Works Associations

The 1946 review of the literature constitutes the fifteenth assembled by the Research Committee of the Federation. With the general objects in mind to summarize the contributions made, to appraise the value of the contributions briefly, to indicate progress made, to aid the busy worker, to make available material published in out of the way places, and to afford a convenient list of references, the aim behind the review which is perhaps not the least important is to arouse interest by pointing out certain developments and possibly stimulating further research.

Naturally, progress made during any given year may be very sketchily indicated. To assay trends and developments more is needed than an annual review. During the last 10 to 15 years sewage treatment has become more and more stabilized and standardized. Mechanization has progressed, but no striking new developments have taken place. It is quite possible that a critical study of the development over a period of years may show the way to new processes, possibilities of improvement of existing processes, and reductions in cost.

Within the next ten years there will undoubtedly be a remarkable development in industrial waste treatment. Several industrial groups have organized committees, boards and councils to investigate existing conditions and methods of treatment as well as to develop processes more suitable to the industries concerned than those available.

Although the war has ended, a renewed upswing in research is not yet reflected in this review. Some interesting and valuable papers have been published. The outstanding report on sewage treatment in military installations contains practically all information necessary to show the present status of sewage treatment, the results to be obtained and the normal difficulties encountered. Study of the report reveals that the difference in characteristics of military sewage as compared with municipal sewage were not sufficient to require many unusual structures or very different procedures from those in standard practice. This makes the report more valuable, because the results are generally applicable to domestic municipal sewage treatment.

Again during this year a considerable number of operation reports were published. However, there has been no material increase in papers dealing with research as distinguished from surveys and plant investigations.

During the war increased industrial activities, discharge of large volumes of wastes to receiving waters and sewage treatment plants, together with a general relaxation of enforcement agencies has left the streams in a poorer condition and aroused many citizens. Hence, interest in new and revised pollution laws has increased.

In respect to plain sedimentation no outstanding papers were published, but several papers dealt with the importance of inlet and outlet design to sedimentation efficiency. Chemical treatment as an aid to sedimentation remained practically stationary.

No fundamental studies on sludge digestion were published. Papers on digestion were primarily concerned with operation and operation difficulties. Supernatant liquor and scum are continuing problems.

Papers on utilization and disposal of sludge did not introduce important new procedures. Although a number of papers were published on mechanical equipment, they described mostly improvements of existing devices. Of interest were the newer methods of sludge heating by a submerged gas-burner and by the revival of live steam injection.

Activated sludge papers were primarily concerned with operation, together with several contributions on air diffusion media, but no important fundamental studies were reported.

Industrial waste treatment was widely discussed. Perhaps most active was the discussion of paper and pulp wastes, followed by some papers on pickling liquors, food wastes, petroleum and plating wastes. There seems no doubt that the number of papers on industrial wastes will gradually increase.

An interesting new hypothesis was advanced during the year on the manner in which chlorine accomplishes bactericidal action. This appears to be at least the eighth hypothesis to have some supporting circumstantial evidence. The chances are that this "enzyme-trace substance" hypothesis brings the question closer to solution, even if it does not explain all phenomena.

The analytical procedures for the examination of sewage and waste progressed, but by no means as rapidly as is necessary. It appears that concerted effort will be needed to make more rapid progress.

A large number of papers appeared on stream pollution. Most of them pertained to abatement and control, rather than to the biology and chemistry involved.

In general, the number of papers published during the year was relatively large, but only few were outstanding and will remain as guide posts for the future.

The Research Committee presents its annual review with the understanding that it is not a complete enumeration of all papers published during the year, but a more or less critical survey of the science and progress of the art.

General

Sewage-borne Disease

A plea is made by Clark 56 that in the design and operation of sewage treatment plants public health aspects should not be overlooked because sewage is still a potential health hazard.

Hamlin (96) reported the presence of cysts of amoebic dysentery and eggs of roundworms, tapeworms and hookworms in Johannesburg sewage. Screens, settling tanks and coarse-grained biological filters were not adequate in removing these organisms. The only effluent free from parasitic cysts and ova was that from slow sand filtration. The presence of poliomyelitis virus in the effluents from primary and trickling filter units was verified by injection into monkeys. Sand filter effluent did not contain the virus.

The effectiveness of "free" chlorine residual in inactivating the poliomyelitis virus was reported by Ridenour and Ingols (179). A 0.2 p.p.m. dosage of "free" chlorine residual inactivated a 1:500 dilution of the virus in 10 minutes. With a 30-minute contact period 0.1 p.p.m. was sufficient. Evans and Osterud (72) reported that the poliomyelitis virus was unable to grow on sewage protozoa.

Sulfides in Sewage and Their Effects

The extensive investigations on the sulfide problem in the sewers of the Los Angeles County Sanitation Districts was presented by Pomeroy and Bowlus (170). The conclusion was reached that sulfides are produced only by the slimes and sludge deposits, and not in the flowing body of the sewage. The origin of the sulfide is mostly, but not entirely, the sulfates in the sewage. Sulfide production takes place over a wide range of pH. The strength of the sewage, area of biologically active surfaces and the temperature determine the rate of sulfide production. The velocity of flow in a free-flowing sewer also plays an important part, since above a critical velocity the deposits and slimes responsible for the production of sulfides are scoured and the sewage is kept in a well aerated condition. Under these conditions sulfides which may be present are actually oxidized. The critical velocity is about 3 ft. per second. Minimizing pressure lines and points of high turbulence would also decrease sulfide production and subsequent sewer corrosion. Of the protective measures for concrete sewers, clay liners of low porosity are recommended. Other measures to curb the rate of sulfide production are: dilution of sewage, decreasing the B.O.D. of sewage by treatment, exclusion of industrial wastes of high temperature and organic content, mechanical or chemical cleaning of sewers, aeration and ventilation. The last measure is effective by drying out the walls and preventing the conversion of H_2S to H_2SO_4.

Hammerton (97) discusses the corrosion of concrete as affected by the character of the water. Hard waters are not as aggressive to concrete as waters containing carbon dioxide. Sulfates in the water react with the ingredients of cement to cause damage. Water containing less than 100 p.p.m. of sulfate is not dangerous. Above 1,000 p.p.m., sulfates become an important risk. Aluminous cement and the addition of siliceous material to cement increase its corrosion resistance. Surface coatings to overcome sulfide corrosion have not proved entirely satisfactory.

Septicization of sewage as a means of increased clarification is suggested by Watson (220). Detention periods of 18 hours gave a purification of over 40 to 50 per cent.

By-Products and Recovery

(For normal uses of gas see section on sludge digestion, and for fertilizer production see section on sludge disposal.)

An unusual use of the digester gas is described by Wilson (223). Due to shortage of formaldehyde in South Africa during the war, a process was developed for the conversion of methane in the gas to formaldehyde. Direct oxidation of methane to formalin proved impractical, but it was converted to methyl alcohol by the use of nickel as a catalyst at 950° C. by passing compressed hydrogen and carbon monoxide. The alcohol was then dehydrogenated to formaldehyde.

Recovery and purification of sewage grease at Johannesburg, South Africa was also reported by Wilson (224). From 1,200 to 1,400 lb. of crude wet grease, about 400 to 500 lb. of mixed distilled fatty acids could be obtained, yielding about 150 lb. of "oleic" acid, 300 lb. of "stearic" acid and 50 to 100 lb. of still residue grease. The products made excellent shaving soaps, creams and other cosmetics.

Plant growth substances (auxins) were found by Chaplin and Regan (54) in raw sludge. The auxin content was greatly reduced by air drying. Activated sludge had a lower auxin content than fresh sludge.

Miscellaneous

The pH-alkalinity factor is suggested by Hood (110) as playing an important role in biological oxidation proc-

esses, just as it does in chemical treatment processes. While ample pH-alkalinity value must be present to act as a buffer, values that are too high have a detrimental effect on treatment. The effect of digester supernatant returned to the sewage flow is mainly through raising the pH-alkalinity values of the sewage. The normal drop of pH-alkalinity values in biological oxidation processes, on which this hypothesis is based, could be the result of the treatment rather than the cause of the efficiency of treatment.

The performance of a few oxidation ponds is discussed by Caldwell (49) and in the Report on Sewage Treatment at Military Installations (158). Removals by the oxidation ponds were 43 per cent of suspended solids and 76 per cent of B.O.D., after primary sedimentation. Suspended solids and B.O.D. of the effluent from the ponds increased during the summer due to the growth of algae.

The threshold toxicity concentrations of 38 sodium salts, the anions of which occur in industrial wastes, on *Daphnia magna* are given by Anderson (8) using the method described previously by the author. All salts were toxic in concentrations high enough to exert an unfavorable osmotic pressure. In this group belong acetate, bromide, chloride, formate, nitrate, sulfate and bicarbonate anions. Toxicity with other salts was obtained at lower concentrations and were due to other causes than an unfavorable osmotic pressure.

Analytical Procedures

In the methylene blue stability test the presence or production of oxides of nitrogen due to nitrification before or during the incubation of samples insures greater stability more or less comparable to natural stream conditions. On the other hand the 5-day 20° C. B.O.D. registers a lower stability of samples in proportion to the nitrification which occurs during the incubation period. The inability of the B.O.D. test to differentiate between the oxygen demand caused by carbonaceous oxidation and nitrification has been a frequent criticism of the test.

Abbott (1) of Shanghai, China, circumvented the nitrification interference by determining both the 2-day and 5-day 20° C. B.O.D. The magnitude of the latter and the ratio of the two was used to interpret the stability of a sample. Subsequently the B.O.D. test was standardized at 20° C. for 3 days with the following advantages: (*a*) the bulk of nitrification interference was eliminated since nitrification occurred after the second and usually the third day, (*b*) the time (3 days) represented one-half of the first stage carbonaceous demand, (*c*) less incubator space was needed and the results were available in 3 days.

Sawyer (187) chose to eliminate nitrification interference on activated sludge effluents by flash pasteurization of samples at 60–80° C. for a few seconds prior to preparing dilutions with seeded dilution water and incubating for five days. The results appear promising and flash pasteurization of raw sewage showed no radical change in the 5-day B.O.D. Although flash pasteurization may be considered an undesirable technique for routine testing, the method is promising to study a desirable temperature and incubation period, or specific antiseptics which would eliminate nitrification interference in the B.O.D. test of secondary treatment effluents and river waters.

Simpson and Alexander (194) report that medium porosity sintered glass crucibles gave total suspended results comparable to the Gooch crucible method. No. 5 porosity crucibles clogged readily and coarse porosity crucibles do not retain all of the suspended solids. Young and Liebowitz (234) use a paper mat and filter aid for the rapid filtration of suspended solids through a Gooch crucible without the use of vacuum other than a self-induced 8-in. waterleg.

Jones and Summers (118) report a field assay of the quality of sewage effluents consisting of adding to 50-ml. samples in each of four Nessler tubes, 2 ml. of H_2SO_4 (25 per cent by volume), followed by 0, 2, 4, and 6 ml. of N/80 $KMnO_4$, respectively. After mixing and standing for 30 minutes, the last tube in which the color has been discharged is noted. If the last tube is colorless, the effluent is very unsatisfactory, if the second tube remains pink the effluent quality is very satisfactory. Bezel (39) has shown that cerium sulfate is readily applicable for testing the quality of natural and drainwaters. The reagent is superior to the $KMnO_4$ procedure because of the stability of the oxidizing agent and of the titers.

Scharer (188) was issued a patent (189) covering a method of determining available chlorine. Ortho-tolidine reagent highly buffered at pH 4.0 will react to produce a pale blue-blue-green-yellow-orange-red color change depending on the ratio of ortho-tolidine to chlorine or chloramine in the test sample. In the residual chlorine range of less than 1 p.p.m. Cl it is probable that only varying but distinctive shades of blue will be produced. Palin (162) uses a p-amino dimethyl aniline reagent for determining chlorine and chloramine. Stumpf and Green (197) suggest the use of a proteolytic enzyme papain (merk) to measure residual chlorine by the inactivation of the enzyme.

Improvement in the potentiometric titration of chlorides was reported by Yeck and Kissin (232). No interference was encountered from the relatively large amounts of heavy metal ions and impurities in a system of silver wire and silver chloride electrodes with an electronic voltmeter titrimeter. The acidified sample was titrated with standard $AgNO_3$ to an abrupt swing at the equivalence point.

A colorimetric determination of iron in water by Caldwell and Adams (50) uses O-phenanthroline which reacts with iron in the ferrous state over a wide pH range to form a highly colored orange-red product. There is little interference with other ions. The results were 10 per cent lower than with the thiocyanate method.

Sulfides in concentrations exceeding 0.01 N as in sulfate pulp black liquors were potentiometrically determined with the use of a glass electrode and a standard silver salt titration by Borlew and Pascoe (40). Field and Oldack (76) developed two colorimetric methods for determining the hydrogen sulfide content of gases. After scrubbing 0.1 cu. ft. or more of sample in sodium hydroxide the sulfide is converted to bismuth sulfide and the suspension assayed by photometric analysis, or in the more sensitive test, the sulfide is made to react with a uranyl-cadmiun reagent and analyzed by visual comparison with standards. The latter method will measure as low as 0.11 grains per 100 cu. ft. from a 0.1 cu. ft. sample with an accuracy of 10 per cent.

Sedimentation

Several interesting papers have appeared on improved design of inlets and outlets for sedimentation tanks. Walker (213) recommends that "a sizeable amount of the influent end of the tank should be partitioned off by means of a permeable baffle. One end of the tank is then used for the dissipation of entrance and density current eddies." Escritt (71) discusses the elbow type inlet and points out the effect of different types of baffle plates across the face of the inlet. He recommends the use of tees instead of elbows, and preferably tees provided with an extension of straight pipe and a baffle plate at the lower end. Kin (123) recommends the use of dropped inlets for secondary sedimentation tanks in activated sludge plants. A sheet metal conduit with flared exit discharges the influent below the surface of the sludge blanket.

Both Walker and the Subcommittee on Sewage Treatment at Military Installations (158) discuss the importance of a low overflow rate for effluent weirs. Walker recommends about 5 g.p.m. per ft. of weir in order to prevent a high velocity of approach from stirring up particles which would otherwise settle. The subcommittee shows mathematically how a high velocity of approach causes a large proportion of a sedimentation tank to be ineffective. This volume varies as the square of the overflow rate.

Walker embodies these ideas in his "double flow tank." The water enters the middle of the tank and flows both ways toward the effluent ends. Two-sided effluent weirs are placed more or less continuously at intervals of 9 ft. and cover the entire surface of the tank. Tests showed the flowing through period to be 90 per cent of the theoretical detention period of 90 minutes. Riddick and Johnson (178), on the basis of their experiences at the Belgrave sewage treatment plant, recommend that inlet flumes be tapered proportionally to flow so as to maintain a velocity of 1 f.p.s. at all inlet ports; addition of a flocculator for agglomeration and to smooth out daily differentials in temperature and suspended solids; covering over of the sedimentation tank to prevent short-circuiting through thermal overturns; and adjustable effluent weirs of sufficient length to prevent high heads during peak flows.

Paterson (165) describes the design, construction, and operation of a spiral flow circular sedimentation tank for a water treatment plant following the design evolved by Walton and Key (214). Water enters through a vertical slot in the outside wall and is directed at an angle of about 60° inwards from the tangent at the inlet. "The clarified water was withdrawn over a drowned weir extending over rather more than one quadrant along the periphery of the tank and so positioned relative to the inlet that the water would tend to pass completely round the tank before passing out over the weir, which is drowned to reduce the velocity of approach." The ratio of the capacity of the tank to the output per hour was 4.25. He concluded that "this type of sedimentation tank is highly efficient at its designed output" (95 per cent removal of suspended solids using alum and lime as coagulants), "and that even when heavily overloaded its efficiency is not greatly impaired" (75 per cent removal at four times design flow).

Lee and Babbitt (129) present another method of using a control section to regulate velocities in grit chambers of rectangular section. They use a Parshall flume instead of a Venturi flume as originally proposed by Bushee (47).

Difficulty with rising sludge in sedimentation tanks following trickling filters is reported by Mountfort (155).

Chemical and Mechanical Treatment

No developments in the treatment of sewage with chemicals have been published and it would seem that the use of chemicals has been confined to chlorination, industrial waste treatment and sludge conditioning. These phases of chemical treatment are covered in other sections of this report.

Biological Filters

The recirculation of a secondary tank effluent through an experimental filter 116 ft. in diameter and 6¼ ft. deep was practiced at the Minworth Works in Birmingham, England. The results of almost 3 years operation were reported by Mills (146). With rates of application up to 250 gal. (Imp.) per cu. yd. per day, B.O.D. values of less than 17 p.p.m. were obtained with considerable amounts of nitrates. The recirculation ratio was 1:1. With similar rates of application on double alternating filters without recirculation, B.O.D. and nitrate

values were comparable to the recirculated filter effluent. The recirculated filter ponded during the winter and spring months.

In the double alternating filter most of the work was done in the primary unit, according to Mills (147). The application of poor effluent from the primary filter to the secondary filter resulted in rapid deterioration in the condition of the latter. During warm weather the B.O.D. of the secondary filter effluent was greater than that of the primary effluent due to nitrification of the incubated sample. Ponding was encountered on the double filtration unit during the winter. Daily change in the order of filters gave better results than weekly change.

Tomlinson (206) has reported on the growth and distribution of biological films in standard and alternating filters. On standard rate filters, film in the top 4 in. increased at low temperatures, while on alternating filters film grew about three times faster in summer than in winter. This difference was attributed to the great effect of scouring organisms in the top layers of the standard rate filter during the summer months. Tests on standard rate filters designed to eliminate the effect of the scouring organisms showed the summer growth to be about twice as heavy as the winter growth. Studies on vertical distribution of filter growth showed only about 50 per cent more accumulation in the alternating filters in spite of the increased sewage load, which was from 3 to 4 times that applied to the standard filters. From 54 to 58 per cent of the total amount of film was found in the bottom two-thirds of the alternating filter and 35 to 43 per cent in the bottom two-thirds of the standard filter.

Allen, Tomlinson and Norton (6) present data on bacterial removals accomplished by standard and alternating filters. Best bacterial data were obtained using nutrient agar plates and incubation at 20 or 30° C. Bacterial removals ranged from 72 to 95 per cent in the low rate standard filter plant and from 45 to 75 per cent in the plant using alternating two-stage filtration dosed at four times the rate used in the standard plant. With standard filters the total count in the settled effluent was usually in excess of 300,000 per ml., and in the settled effluent from the alternating double filters the total count was usually in excess of 1,000,000 per ml. The standard filter also gave much better removal of coliform organisms. The authors found very poor correlation between B.O.D. removals and bacterial removals.

Montgomery (149) discusses single and two-stage high capacity filters with special reference to operating results and design factors relating to "Aerofilters." Several causes of inferior operating results are listed. Simpson (193) relates his experiences in the operation of "Biofilters" at an army camp and indicates that a recirculation ratio of 2 to 1 is necessary for efficient operation. Application rates in excess of 12 m.g.d. were found necessary to control filter flies. Efficiency was found independent of B.O.D. loading over the range of 0.2 to 1.4 lb. per cu. yd. per day. Increased recirculation, to cut the detention time in primary settling tanks from 4.5 to 3.0 hours, decreased suspended solids removal but increased B.O.D. removal. The author did not mention the role of dilution in these results.

Roberts (180) reports results of mixing trickling filter effluent with settled sewage to determine the value of recirculation. British investigations have not explored the range of high rate filtration, as represented by loadings of 3,000 or more lb. B.O.D. per acre-ft., which are common practice in the U. S.

The use of DDT in filter fly control has been investigated by Brothers (42) and Carollo (51). Both filter

flies and their larvae were found to be subject to action of DDT. Application of 0.2 lb. per acre was found sufficient to kill the flies when applied to exterior surfaces but did not reduce the larvae population in the filters. Application of relatively high concentrations of DDT to the filters in admixture with sewage, and a 30-min. contact period, gave over all larval reductions of 44 to 95 per cent with about 80 per cent reductions at the 2-foot level. Emission of flies was controlled quite effectively for about 30 days. The dosage required per unit volume of filter was not determined as both investigators applied dosages (0.5 to 1.0 p.p.m.) based upon the 24-hour sewage flow, even though the DDT was added over a very short period during the 24 hours. Filter growths are reported to have improved after DDT treatment and no ill effects were noted on B.O.D. removals.

Experiments on the treatment of a small experimental filter with DDT were reported by Tomlinson (207). DDT was applied in the form of (a) a powder, at the rate of 300 lb. per acre and (b) an emulsion in naphtha or kerosene, at the rate of 50 to 100 lb. per acre. Over 90 per cent of the larvae of *Anesopus* and *Psychoda* were killed. Bacteria, fungi collombolla and enchytrated worms were unaffected.

Dreier (67), in a summary of operating data collected from 31 standard trickling filter plants, has shown that reasonable B.O.D. removals (80–90 per cent) can be obtained with loadings as high as 500 to 800 lb. B.O.D. per acre-ft., or 0.3 to 0.5 lb. per cu. yd. Some reporters continue to present summer data and withhold winter data. A chart showing year-round operation at Madison, Wis., where wide seasonal fluctuations in temperature occur, is shown.

A review of the performance of biological filters at military camps is included in the report "Sewage Treatment at Military Installations" (158). For analysis of the data, the filters were classified into four groups as follows:

I. Deep Filters without Recirculation. Basis of design was 4,620 persons per acre-ft and average loading was 64 per cent. With filter loadings ranging in the main from 253 to 903 lb. B.O.D. per acre-ft., settled effluent B.O.D. ranged from 14 to 68 p.p.m. and over all B.O.D. removals from 95.0 down to 82.6 per cent. Performance in removing suspended solids was similar. Filters in this group removed 70.5 per cent of the B.O.D. applied to them. Final effluent B.O.D. averaged 38 p.p.m.

II. Deep Filters with Recirculation. Basis of design was 23,100 persons per acre-ft. and average loading was 71 per cent. The mean value of recirculation was 1.18. With filter loadings ranging in the main from 245 to 2,870 lb. B.O.D. per acre-ft., the settled effluent B.O.D. ranged from 16 to 73 p.p.m. and over all B.O.D. removals from 93.3 down to 77.2 per cent. Suspended solids removals were similar. Filters in this division removed 36.6 per cent of the applied B.O.D. Final effluent B.O.D. averaged 44 p.p.m.

III. Shallow Filters with Recirculation. Basis of design was 23,100 persons per acre-ft. and average loading was 73 per cent. Average depth of filters was 3.35 ft. and recirculation ratios ranged from 0.51 to 10.5 with a median of 2.80. With filter loadings ranging in the main from 792 to 6,450 lb. B.O.D. per acre-ft., the settled effluent B.O.D. ranged from 42 to 81 p.p.m. and over all B.O.D. removals from 92.3 down to 72.2 per cent. Over all suspended solids removals varied from 80.0 to 91.4 per cent. Filters of this division removed 52 per cent of the applied B.O.D. and the average B.O.D. of the final effluent was 45 p.p.m.

IV. Two-Stage Filter Plants—(*A*) First Stage. With B.O.D. loadings

ranging from 988 to 8,680 lb. per acre-ft., intermediate tank effluent B.O.D. ranged from 41 to 181 p.p.m. and B.O.D. removals by filter and settling tank ranged from 23.7 to 52.4 per cent. (*B*) *Second Stage.* With B.O.D. loadings ranging from 192 to 930 lb. per acre-ft., the final settling tank effluent B.O.D. ranged from 11 to 66 p.p.m. and removals of B.O.D. ranged from 14.3 to 26.8 per cent. Over all plant removals of B.O.D. ranged from 93.3 down to 84.8 per cent and of suspended solids from 94.9 to 81.9 per cent.

Equations for determining the efficiency of first and second stage filters have been developed from the data and several examples are given to illustrate how the equations can be used to determine the anticipated B.O.D. of effluents and the per cent removals by proposed plants.

For two-stage plants, the data indicate that primary and secondary filters should be of approximately the same size to keep filter volumes at a minimum.

Activated Sludge

Two excellent committee reports have discussed the activated sludge process during 1946. The Third Progress Report of the ASCE Committee on Sewerage and Sewage Treatment (166), Langdon Pearse, Chairman, has reviewed the status of activated sludge with particular attention to plain sewage aeration, high rate activated sludge, maintenance of diffuser plates, the concentration of excess sludge and the design of final settling tanks.

The Subcommittee on Sewage Treatment of the Committee on Sanitary Engineering, National Research Council, F. W. Mohlman, Chairman, has reported (158) on sewage treatment at military installations. The committee concluded that, as presently designed, activated sludge plants are not sufficiently flexible to handle the variations in flow and load that are to be expected in military posts. The percentages of removal of B.O.D. and suspended solids were not higher than from a number of other types of plants. Because of the large quantities of air used per gallon of sewage treated, the activated sludge plants were expensive to operate. Most of the time the sludge indices were high (over 200) and to prevent the loss of sludge over effluent weirs, application of chlorine or coagulant to the return sludge, as well as constant vigilance on the part of the operating staff, were required.

Out of a total of 126 sewage treatment plants in Canada (219), 47 are activated sludge plants. These plants have a total design capacity of 59 m.g.d. and serve a population of 550,000. The average capital cost was $143,000 per m.g. of design capacity.

Air Diffusion Media

The selection of the best type of air diffusion media and the maintenance of plates and tubes are important in the design and operation of activated sludge plants. Mohlman (148) reported that various types and arrangements of diffuser media are being tried at the Chicago Southwest plant to determine the best for future use. The media being tested include plates of different permeabilities, tubes and slotted brass pipe.

The maintenance of tubes and plates at Cleveland's Southerly plant has been described by Flower (79). The plant contains two aeration tanks, one equipped with 1,500 Aloxite plates having a permeability of 40 and the other with 1,500 carbon teardrop tubes, grade 20, with a permeability rating of 26 c.f.m. $\pm$ 10 per cent at 2 in. pressure and a submerged rate of 6.0 c.f.m. at a differential pressure loss not to exceed 7.2 inches. The plant was placed in service in October, 1938. The most serious clogging occurred in 1939 when the settled sewage contained, on the average, about 100 p.p.m. of iron. The tubes became clogged within about three months of the time that they

were installed. Washing with water did little good. They were cleaned with acid and only 700 tubes replaced in order to increase the rate of air flow from 2.5 c.f.m. to 5.0 c.f.m. per tube. In a very short time they clogged again and were again cleaned with acid and coated with a water-insoluble grease. This was also unsatisfactory. Many of the hoisting cables used to raise the tubes have corroded enough at the surface level of the sewage to cause them to fail. The tubes are now cleaned each spring and fall. The Aloxite plates were removed and acid cleaned quite a number of times during this time. In 1945, the aluminum plate holders had corroded so badly that the plates were replaced with perforated pipes.

At Marshalltown, Iowa, Lovell (132) cleans the diffuser tubes by boiling them in 20 per cent caustic soda for two hours, then rinsing and soaking them in 30 per cent muriatic acid for four hours, followed by a final rinse. Lovell has recommended that new tubes be purchased for one tank in order gradually to renew the tubes which have been in service five years. The diffuser tubes in the mixed liquor channel are also badly clogged.

Mohlman (148) reported that chlorination of the air has been of no value in cleaning clogged plates at the Southwest plant.

At Ann Arbor, Michigan (229), the aluminum plate holders in the aeration channels disintegrated and the diffuser plates have been replaced by galvanized pipe manifolds with celluloid capillary tubes for diffusers.

Operation

Witcher (229) stated that, partly because of insufficient return sludge pumping capacity and partly because the sludge was held too long in the final tanks, the Ann Arbor, Mich. plant (designed for 4.5 m.g.d.) was unable to treat more than 3.8 m.g.d. In 1942, the aeration tanks were operated without sludge return fairly successfully for several months, but the effluent was not up to the standard of activated sludge. Installation of a larger return sludge pump and speeding up the sludge mechanisms in the final tanks from 1 to 3 f.p.m., together with the use of the Mallory method of control, has enabled the plant to operate consistently and successfully as an activated sludge plant handling more than the design flow.

Mann (140) has also used plain aeration of sewage at the Ley Creek plant in Syracuse. He operated half the plant without return sludge for six months. With an average of 8.2 hours aeration, he obtained 82 per cent removal of suspended solids and 87 per cent removal of B.O.D. The effluents were turbid. The waste sludge concentration averaged 2.9 per cent as compared with 1.5 per cent for the excess activated sludge.

A comparison of the results obtained by plain aeration and by high rate activated sludge (modified sewage aeration) has been made by Setter (191), and he concluded that the results from high rate activated sludge are superior to those from plain sewage aeration.

Lovell (132) found that silt and clay which entered the sewers during flood stage in the river greatly helped the operation of the Marshalltown, Iowa activated sludge plant. The volatile content of the solids dropped from about 80 per cent to about 35. The sludge index improved and the dissolved oxygen remained high. The solids in the aeration tank rose to 7,800 p.p.m. and in the return sludge to 28,000 p.p.m.

At Peoria, Kraus (126) has greatly improved the sludge index by adding digested sludge to activated sludge and by aerating the mixture in a special tank before mixing this conditioned sludge with the conventional return sludge. Large amounts of nitrate are formed during the aeration of digested

sludge. He believes that, in addition to controlling the sludge index, the use of digested sludge increases the load capacity of the activated sludge plant, eliminates the supernatant problem in digesters and changes the activated sludge process so that shock loads can be handled without the use of additional air.

Adams (3) has found that an average chlorine dosage of 5 p.p.m. based on the return sludge flow has been very beneficial in controlling the sludge index at Tenafly, N. J. The chlorine is added to the return sludge just before it mixes with the sewage. The contact period is only about a half minute before the sludge joins the sewage and another half minute before the mixture reaches the aeration tank. Chlorination is generally started when the Donaldson sludge index drops to 0.85 during high flows or to 0.60 during low flows. It is usually stopped when the index rises to about 1.10. Improvement in the index can be observed in about two days and the desired result obtained usually in less than a week.

Concentration of waste activated sludge in primary settling tanks has been practiced in a number of plants. According to Wirts (221), excess activated sludge at the Cleveland Easterly plant was pumped to the primary settling tanks during weekends for two months but this practice was discontinued because of the return of the fine activated sludge floc to the aeration tanks.

The return of waste activated sewage and digester decant liquor to the primary settling tanks at the Willow Run sewage treatment plant caused overloading of the primary tanks and interference with the activated sludge process. Herda (102) reported that chlorination of the waste activated sludge and digester decant liquor with 2 to 8 p.p.m., based on the excess activated sludge flow, caused a great improvement in settling in the primary tanks and permitted the discharge of a clear final effluent.

As an experiment, Deeley (63) at Coventry, England, divided the activated sludge plant into five more or less separate units and for several months, all of the sewage was given partial treatment in one unit followed by full treatment in the four remaining tanks. In this way, the total capacity of the plant was increased 50 per cent.

In three army sewage treatment plants in Florida, the algae and bacterial slime were carefully removed from the galvanized splash plates of mechanical aerators. Every peak load of soapy, alkaline water resulted in a gray, non-settling and sick activated sludge. Carothers (52) discovered that the algae and slime were important in purification and when they were not removed, the plant operated satisfactorily.

The view now commonly held in England (27) seems to be that if it is advisable to carry purification by the activated sludge process to the nitrification stage, then a high degree of nitrification is desirable in order to avoid rising sludge—"A little nitrogen is a dangerous thing." Lockett at the West Middlesex works maintains nitrate nitrogen at 8.0 p.p.m. or more.

Design

Large scale experiments, reported by Wishart, Jepson and Bradwell (226) showed that there is no advantage in having aeration channels more than 1,000 ft. long nor any disadvantage with channels as short as 342 feet. A minimum length is probably required to avoid short-circuiting. The most important factor in design is the relative construction costs.

Price and Withnell (172) described the Rochdale Kessener brush aeration plant which was completed in 1944. The plant, designed for a dry weather flow of 1.6 m.g.d. (Imp.) consists of six units, each comprising two aeration tanks and four settling tanks. Each

unit is self-contained and the sludges are not mixed. Stainless steel combs revolving at 140 r.p.m. along the inner wall of each tank aerate the sewage. The combs or brushes touch the surface of the liquid, throwing it outward to form a spiral flow. The plant can be operated with step aeration. The sludge enters the first bay and the sewage may enter the tank with the sludge or at the inlets to the second or third bays. The amount of aeration can be varied somewhat by adjusting the sewage level and therefore the brush immersion. The aeration tanks are designed for 16 hours detention at the dry weather flow and the final tanks for six hours. The sludge is returned by the aid of a sludge elevating wheel which tends to break up the floc less than a centrifugal pump.

Fischer (77) reported that Imhoff has designed a new activated sludge plant for Berlin. The interesting feature of the design is that the plant, planned for a population of 1,300,000, is being laid out in three separate groups, each of which is divided into three sections. Each section can be operated independently as a separate plant. It is planned that the treatment in one or more sections will be carried to a high degree of nitrification and the final effluent returned to the raw sewage entering all three plant groups. In this way, it is believed that the septic sewage can be made more amenable to treatment and odors reduced.

Chlorination

An inventory of U. S. sewage treatment facilities (70) shows chlorination to be employed in 1,313 plants. This figure represents an increase of 30 per cent in the number of plants using chlorination, as compared with the number reported in a similar survey made eight years previously.

Chlorination Research

A specific explanation of the manner in which chlorine accomplishes bactericidal action has been presented by Green and Stumpf (92). In accordance with the "enzyme-trace substance theory," these authors infer that chlorine must inhibit some enzyme reaction. They show that chlorine reacts to inhibit the oxidation of glucose by the bacterial cell; once the power of glucose oxidation is lost, the bacterial cells die. The results of their study also indicate that chlorine has an almost instantaneous action in this respect and that the reaction is not reversible, while iodacetic acid and organomercurials are bacteriostatic agents whose effects are strictly reversible.

Up to the present time, there is no reason to believe that the virus of poliomyelitis is of importance in the transmission of this disease, nor is there any evidence that this disease has ever been spread by a contaminated public water supply (7). Of theoretical interest, however, are two research studies made to determine the effect of chlorine, in amounts comparable to those commonly used in water purification, on the poliomyelitis virus (131) (179). The results of these studies show that chlorination adequate to provide free available chlorine residuals will inactivate the virus in a contact period of 30 minutes or less when using the Lansing strain of poliomyelitis virus and mice as the experimental animals.

Free available chlorine residuals are seldom attained in sewage chlorination, but two new laboratory methods (200) (163) for determining such residuals are of technical interest.

Chlorine Applications

In order to apply chlorination with maximum efficiency and economy, Faber (73) recommends an understanding of the principles involved and reviews some of the chemical and bacteriological reactions which occur.

Pomeroy and Bowlus have provided an exceptional report (170) on sulfide

control research in Los Angeles. Chlorination has been successfully used in the control of sulfides in sewage during the past twenty years. Sulfides are now known to be produced only in slimes on the sides of the sewer, and continuous or intermittent chlorination may be employed to sterilize slimes. The present program in this city represents a compromise: locating chlorinators where the dose applied will destroy sulfides entering the trunk sewers and, by using moderate excess doses, thus to keep sulfides from being produced for a distance of 2 to 3 miles downstream. An average of 12 to 15 lb. of chlorine is used for each pound of sulfide eliminated.

An extensive report (158) describes the application of chlorine for a number of purposes at military installations, especially for odor control (by prechlorination), and for disinfection and B.O.D. reduction (by post-chlorination). Only one of five activated sludge treatment plants reported did not employ chlorine. At four of the plants chlorination of return activated sludge (continuous or intermittent) provided a successful method for control of bulking.

Three applications of chlorination at the Cleveland, Ohio, Easterly activated sludge plant have been reported by Wirts (228). Post-chlorination is employed during the summer months to protect bathing beaches—a dose of 4.4 p.p.m. is required to provide a residual of 0.5 p.p.m. after a 5-min. contact period. A full-scale study of aero-chlorination (prechlorination in conjunction with preaeration) applied at a dose of 2.4 p.p.m. for 33 days, demonstrated that a marked improvement in grease separation could be accomplished. The chlorination of return sludge (at an average rate of 8.0 p.p.m. during a 21-day test period) proved effective in reducing the sludge index in chlorinated batteries as compared with that of batteries receiving unchlorinated sludge.

Chlorination for Disinfection

In accordance with a recent court decision that chlorination equipment be installed, a large-scale pilot plant was used (89) at the Hyperion screening plant of the city of Los Angeles to determine chlorine requirements and disinfection efficiency. Operating results indicated an average chlorine dose of about 150 lb. per m.g. to be required for accomplishing the desired degree of bacterial kill, using a contact period of about 10 minutes. Later studies (43) showed a 20 per cent satisfaction of chlorine demand plus the application of 1.0 p.p.m. Cloroben to constitute an efficient combination of chemicals for long continued bactericidal effect. It was reported that the up-sewer application of Cloroben alone, in a dosage of 1 to 2 p.p.m., would reduce bacterial population 50 per cent, would retard the formation of hydrogen sulfide, and would emulsify greases.

According to reports (41) (215), military forces have made practical use of evidence that the cysts of *Endameba histolytica* and the cercariae of schistosomiasis, in sewage polluted water, can be destroyed by chlorination. Chlorine is also an effective ovicide for eggs of *Aedes aegypti* (100), but large concentrations—50 to 100 p.p.m.—appear to be required for this purpose.

Chlorination in Trickling Filter Treatment

A review of practices in the operation of "standard rate" trickling filters (67), is based by Dreier on data from 31 representative plants. Occasional applications of chlorine, in moderate doses, have been found of value at some plants to control excessive surface growths, and many plants have experienced better operation when a small continuous or semi-continuous chlorine dosage is applied to the settled sewage. Chlorine is used for filter fly

control with success at some plants but with mediocre results at others. Eleven of the plants employ chlorine effectively for odor control.

Hirsch reports (106) the dose of chlorine generally required for odor control to be 3 to 6 p.p.m., when continuously applied in the wet well or dosing tank, and that dry hypochlorite can be used satisfactorily when applied directly to the bed in the amount of about 10 lb. per 1,000 sq. ft. of filter area. For control of flies, a 3 to 5 p.p.m. dose of chlorine applied at night during low flows, or 100 lb. of hypochlorite per 500 sq. yd. of filter surface, is recommended. Excessive prechlorination (149) ahead of high capacity trickling filters has been found, however, to result in loss of biological growth.

Chlorination in Activated Sludge Treatment

Tapleshay has published (199) a chlorine dosage chart for the control of bulking activated sludge. This chart is based on his formula in which the pounds of chlorine required per thousand gallons of return sludge is computed from two factors: the sludge index and the suspended solids concentration of the mixed liquor. He discusses operating procedures which have been found effective in employing this treatment.

At the Tenafly, N. J., activated sludge treatment plant, Adams (3) has employed return sludge chlorination as a successful means of bulking control for more than four years. When treatment is started soon after the sludge index becomes indicative of bulking, and when applied in a dose of 4 to 8 p.p.m., improvement appears in two days and satisfactory operation is attained in a week. Chlorine treatment is as beneficial in cold weather as in warm, dry weather.

In an overloaded activated sludge treatment plant at Willow Run, Mich., Herda (102) has found chlorination of return sludge to control bulking. A dose of 2 to 8 p.p.m. makes it possible to maintain the sludge in good condition.

Chlorination of return sludge at the Marshalltown, Iowa, plant is reported (132) to relieve bulking conditions.

Chlorination in Industrial Waste Treatment

A new method has been developed for the treatment of wool scouring wastes which materially reduces the pollution load imposed by these wastes, and which permits the recovery of a valuable by-product. Faber and Howard (74) have described the development of this process, utilizing chlorine in the form of calcium hypochlorite, and have described the operation of a full-scale plant where this process is employed.

Studies by Placak and Ruehhoft (169) have shown that chlorination may be used in the pretreatment of butadiene wastes from the synthetic rubber industry. The raw wastes have a 24-hour chlorine demand of about 450 p.p.m., filtration reduces the demand to about 260 p.p.m.; chlorination clarifies and decolorizes the wastes, making it possible to treat larger concentrations by ordinary water purification procedures.

Oeming (160) has described chlorination methods capable of reducing cyanides in electroplating wastes to less than 1 p.p.m. Chlorine requirements range from 2 to 3 lb. per pound of sodium cyanide and a pH value of 11.5 is recommended. Chlorinated lime may be employed on small scale, but the cost of chlorine and the excessive quantities of sludge produced are undesirable features. The use of liquid chlorine and caustic soda provides the most economical method, and one having the widest range of applicability.

Sludge Digestion

Operation

Informative data relative to the design and performance of the digestion

equipment used in military installations are presented in the comprehensive Report of the Subcommittee on Sewage Treatment of the Committee on Sanitary Engineering, National Research Council (158). Although Chapter VIII of this report is headed "Sludge Digestion and Disposal" and contains in Tables 113 to 116 data from eight plants having primary as well as primary and secondary treatment, additional data relative to the digestion of waste activated sludges in five plants (including two listed in Chapter VIII tables) will be found in Table 110 of Chapter VII dealing with activated sludge plants. In all activated sludge plants listed the waste activated sludge was combined with primary sludge in separate digestion tanks. The sludge gas was used to heat digestion tanks, offices, laboratories and control buildings. In seven of the plants listed in Chapter VIII the digester gas yield was 1.25 cu. ft. per capita daily, 13.9 cu. ft. per lb. of volatile matter added and 20.5 cu. ft. per lb. of volatile matter destroyed. The average destruction of solids added to the digesters was 69 per cent of the volatile solids and 57.1 per cent of the total solids.

The methods of digesting the sludge at the Yardley Works of the Birmingham Tame and Rea District Board, England, are presented in the preprint of the report on the subject by Salt (184). The large quantities of sludge at this plant are digested in ten closed primary digesters equipped with floating covers and heated by circulating heated sludge liquor through them. Five open tanks are used for secondary digestion. Three of these are used for second stage digestion and one as a settling tank for producing the supernatant digester liquor used in the heating circuit of the first stage, while the other receives liquor displaced from first stage tanks. The sludge volume is reduced to but one-third of the raw mixed sludge through solids destruction and concentration in digestion. Some sludge gas is used for electric power generation. The power plant contains one gas engine of 34 b.h.p. that has been in operation for 25 years. The largest (150 b.h.p.) is over 18 years old.

Greene (93) suggests that digester capacity should be measured in pounds of volatile solids added per cubic foot of digester space per month. At Jackson, Mich., extensive experience shows that with an average digestion temperature of 85° F. not much more than 0.5 lb. of volatile solids can be digested per cubic foot of total digester capacity per month and still produce fair supernatant. The relative merits and drawbacks of thermophillic digestion are also discussed. A well digested thermophillic sludge will dewater better than an incompletely digested mesophillic sludge. Thermophillic digestion is more difficult to operate and a quick change in temperature of 5 to 10° can completely upset the process.

Sewage Works Engineering (23) presents a digest of its recent Round Table discussions on the operation of Imhoff tanks relative to detention periods, sludge and scum volumes, reversal of flow, skimming and cleaning of slots and sidewalls.

The same periodical also presents a similar digest of its discussions on experiences with sludge gas lines (24) with information about sizes, types, method of installing, protective devices used, causes and correction of stoppages and leaks. Vermette (211) publishes a chapter on the practical aspects of sludge digestion for operators of small treatment plants.

Heating

Keefer (121) describes two novel and simple methods of heating sludge for digestion, either by direct contact of the circulating sludge with the hot flame and combustion gases obtained from a Kemp burner, or by using a similar burner in an enclosed combustion chamber submerged in the sludge being heated. In the former open-type burner, the heat losses are confined to

a minimum and the ebullition of combustion gases circulates the sludge being heated. In the closed type heater, the heat transfer is necessarily through the metallic wall of the tubular combustion chamber, but less pressure is required to force the combustible air and gas mixture through the burner. The open type was tested with success at the Back River sewage treatment works. The closed type will be used in the 27,000 cu. ft. digester of the Reedbird Avenue treatment plant. Although this device can evidently be designed to operate outside the digestion tank it is being installed in the digester at this particular plant.

The idea of heating digester sludge in an efficient device outside the digestion tank so it may be easily and entirely accessible at all times, thus rendering the digestion space free of inefficient heating coils and operational interruptions, is detailed by Langdon (127). This involves an external hot water heat exchanger through which the mixture of fresh and digested sludge is circulated by a pump. It allows preheating and seeding of sludges before addition to the digester, full and effective turnover of the digester contents during digestion and close automatic temperature control. In addition to its provision for straight gas firing it is equipped to be converted to an oil fired unit.

Miles (145) also prefers the foregoing type of heater in his evaluation of the various methods of heating sludge for digestion. Such external heating devices can transfer to the sludge more heat per square foot of exchanger surface than can coils in a digester. Aside from the material advantage of being more accessible for cleaning and repairing, they provide better protection against temperature drops in a digester when unheated raw sludge is introduced directly.

Supernatant

The elimination of the problem of dirty digester supernatant in activated sludge plants by Kraus was reviewed in THIS JOURNAL last year. In a more extensive treatise on the subject (126) he presents further convincing evidence of the effectiveness of the process for using digester supernatant to control the sludge index of the activated sludge process. By means of diagrams and tables he described three periods of operation at Peoria, Ill. At this plant it was thought that frequent bulking of the sludge was brought about by industrial shock loads. The author ably details his means of reducing the inimical effect of these loads on the activated sludge process by what he terms an "interchange procedure." In this procedure he mixes digester overflow with return activated sludge in a separate aeration system (sludge treatment aeration tanks) in order to convert this mixture to an activated sludge of low index. The overflow from these tanks is then added to the normal return activated sludge of high index flowing to the aeration tanks. The procedure of mixing the two activated sludges is called the "interchange procedure." By making the interchange process properly intermittent over alternate periods of 24 hours, excellent control of the sludge index resulted. The author concludes that in addition to eliminating the supernatant problem the process transforms conventional activated sludge treatment from a sensitive process, incapable of continuous high degree purification when subjected to shock loads of organic solutes, to a rugged process with capacity for effectively purifying such shock loads.

Scum

Under a subsequent review heading reference will be found to the role a blanket of cold digester scum played among the causes of explosion of the primary digester at Herkimer, N. Y. (202). The discussions of Taylor's article (203) on the lessons to be drawn from this accident, by Buswell, Hazen, Leclercq, Wenzel and Taylor (204)

center around the problem of scum prevention and removal. Like Taylor, Buswell believes that ample circulation with tank liquor will disintegrate scum blankets. He also argues that floating covers remove explosion hazards when removing scum. Hazen cites an instance of digesting a hard scum blanket by submerging it under a foot of fresh sludge and then 3 or 4 ft. of well digested sludge. Leclercq argues along the lines of experience listed hereinafter by McLean (142), *i.e*, proper mechanical mixing and piping design to allow independent functioning of primary and secondary tanks. Wenzel proposes burying the heating coils in the concrete floor and sidewalls of the digester and using radiant energy for heating the tank contents. Taylor points to the fact that his scum control method of jetting sludge liquor onto the scum layer operated successfully for 8 years at Herkimer until the jet nozzle fell off. He believes there are other methods of agitation, mixing and temperature control beside mechanical stirring and states there is nothing about floating covers to guarantee the absence of floating sludge.

The effects of reducing scum by feeding quantities of ammonium sulfate into one of the digesters at Buffalo, N. Y., are mentioned in the annual report of the Buffalo Sewer Authority for 1943–1944 (44). At times the scum accumulation averaged 12 ft. in depth and contained 20 per cent solids of 70 per cent volatile matter.

The effects of stirring scum properly in order to prevent scum accumulation are detailed by McLean (142). At the treatment plant of the Greater Winnipeg Sanitary District there are four digestion tanks, two of which are equipped with Dorr Turbo-mixers. Prior to the war they were used as primary stage digesters. The two others had no mixers and were used as secondary digesters. When war conditions overloaded the plant all four were used as primary tanks and the elutriation system served as secondary tanks and for elutriation. This gave the operating staff an opportunity to observe the effects of scum accumulation in the digestion tanks with and without mixers. The tanks equipped with Turbomixers give no scum trouble as long as raw feed and temperature are properly controlled. The tanks without stirrers accumulate scum to depths varying from 8 to 14 ft., which has to be removed once a year. This accumulation reduces valuable digestion space. Turbo-mixers installed in the other two tanks would permit the recovery of this lost space and the digestion of 20 to 25 per cent additional raw solids.

Gerdel (87) believes that a large percentage of sewage treatment plants having digesters are troubled with scum problems. He classifies the troublesome effects in two general categories, operational and maintenance, and enumerates the difficulties coming under each heading. The Cleveland Westerly treatment plant has been troubled with scum ever since it started, chiefly because of the fact that stockyard wastes comprise a considerable portion of the sewage flow. These wastes contain paunch manure, which seems to be quite resistant to the digestion process and tends to accumulate as scum. It will be seen from Imhoff's article on the digestion of cow manure, hereinafter reviewed (114), that it is quite necessary to break up such manure scum at least twice daily. Under these conditions and others listed by Imhoff, manure should not be resistant to digestion but should produce copious amounts of gas.

Gerdel aso enumerates methods of scum control and concludes that it is difficult to evaluate the various methods as to comparative effectiveness.

Doman (65) likewise states that the problem of scum accumulation is of the same general pattern for all separate sludge digestion plants and discusses this pattern from the operator's standpoint. The material which rises to form scum must be given the best opportunity to digest. The most im-

portant aids to this end are at least 95° F. temperature, proper pH (6.8 minimum with slightly above 7 preferable), proper seeding of the scum and, by all means, keeping it thin and wet to insure these favorable conditions.

At Ludlow, Mass. (10), the 1-m.g.d. sewage treatment plant has operated since 1941 without the problem of scum accumulation in its novel two-story digesters with fixed covers. Scum formation is prevented by Taylor's method of jetting hot supernatant onto the potential scum blanket. Other interesting features of the two-story digesters are depicted, *e.g.*, the method of trapping gas in the lower story for storage in the upper and using the gas pressure to force supernatant into the upper story where it finally overflows. Bottom jets are also used to facilitate the removal of digested sludge.

The method of circulating hot supernatant liquor through nozzles so as to impinge liquor jets on the scum surface of the digesters will be used in the new Boston plant, as described by Kennison (122).

Toxic Inhibition of Digestion

Rudgal (182) reviews the inimical effects of copper-bearing pickling and rinse water wastes from large copper and brass products industries on sludge digestion at the Kenosha, Wis., sewage treatment plant. Since October, 1940, it has been necessary to operate this plant without the large fraction of domestic sewage that carries most of these wastes, in order to digest the sludge obtained from the remaining fraction of the city's domestic sewage (60 to 65 per cent).

During the period the toxic wastes received treatment the gas production was but 0.5 cu. ft. per lb. of volatile solids added to digestion. After diverting the sewage containing most of this waste the gas production rate became 22 times greater per pound of volatile matter. The author shows that the quantity and form of copper that concentrates in the sludge is the real criterion upon which to base determinations of the deleterious effects on sewage treatment processes. Following this line of reasoning the operating staff at Kenosha believes, quite logically, in expressing copper concentrations in percentages or p.p.m. of dry solids present in the sludge rather, than in p.p.m. Cu in the wet sludge. Thus raw sludge containing 95 per cent water, 5 per cent solids and 2,500 p.p.m. Cu really contains about 5 per cent copper (50,000 p.p.m.) in the dry sludge solids present. This method of measuring copper completely changes the picture of the magnitude of the toxic action of copper on solids.

Rudgal's conclusions are that, due to the quantity and copper content of the wastes at Kenosha, they are to be classed as deleterious to sewage treatment. They should be excluded from the sewer system unless they receive satisfactory pretreatment by the contributing industries.

Gas Utilization

Fourteen dual-fuel engines totalling 19,000 h.p. are scheduled for the various sewage treatment plants in New York City according to an article in *Diesel Power and Diesel Transportation* (20). The author outlines successive phases of modern sewage treatment methods with emphasis on sludge digestion and its value in producing gas for power generation in internal combustion engines. The development of the new dual-fuel engine is shown. This engine is actually a gas engine operating on the Diesel cycle using a pilot injection of fuel oil for ignition purposes. It can operate fully on Diesel fuel or can consume digester gas with only the minimum pilot injection of fuel oil for gas ignition. A Worthington dual-fuel unit now operates at the Tallman's Island plant in New York City. It is rated at 460 b.h.p. There are several conventional

gas engine units operating in various New York City plants.

Burdoin (46) discusses the economics of utilizing digester gas in gas engines. The power available depends on the pounds per day of volatile solids collected and digested. The average power available with primary treatment alone varies from 5.6 to 29.4 b.h.p. per m.g.d. of sewage treated, and with the addition of activated sludge treatment these averages increase to 12.6 and 44.1 b.h.p. per m.g.d.

The proportion of available gas power for pumping will depend on lift and the strength of sewage. Installations are divided into two general classifications, *i.e.*, those employing electric generators and those where equipment is driven directly by the gas engine. The former reduced the available power figures by 25 per cent but provides more flexibility. The latter is preferred in smaller installations where there is usually more than enough power for pumping and possibly for the entire plant load. The most recent development for eliminating the necessity of standby power in case of gas deficiency is the dual-fuel engine. The heat in the engine jacket water and engine exhaust suffices to heat digestion and buildings.

Five years of experience with two Cooper-Bessemer gas engines at the Madison (Wis.) Metropolitan Sewerage Commission plant is outlined by Mackin (139). With a local electric current rate of 1.1¢ per kw. hr. this installation has saved money. Hydrogen sulfide is removed from the digester gas by the use of iron sponge.

Inventions dictated by economic necessity are sometimes more important than those suggested by pleasure, and they are certainly more interesting to the engineer. This statement is exemplified by two interesting and informative reports on the use of digester gas for motor fuel abroad. Six years ago Fuhrman called attention in this country to the resourceful use of washed and compressed digester gas for motor fuel in Johannesburg, S. A., where the cost of gasoline is relatively high. With the scarcity and high cost of this motor fuel abroad during the war it seemed logical that this economic development would be pushed to new limits.

Parker (164) presents an interesting report on the use of compressed methane in twelve motor vehicles at the Mogden Works of the West Middlesex Main Drainage project in England. The methane is obtained from surplus digester gas. The first vehicle was operated on this gas in April, 1942. The gas is first compressed to 20 p.s.i. and about 91 per cent of the original CO_2 is washed out; practically all H_2S is removed by sponge iron. The calorific value is raised from 680 to 822 B.t.u. per cu. ft. The purified gas is compressed by stages to 5,000 p.s.i. for storage in large cylinders. It is transferred to smaller vehicle cylinders at 3,000 p.s.i. and, in being used, this pressure is reduced in two stages to atmospheric.

A lighter automobile uses but 4¼ cu. ft. of gas per mile travelled and heavier cars and trucks use from 9.6 to 13 cu. ft. per mile. Vehicle travelling ranges are from 45 to 80 miles. An average of 173 cu. ft. of this gas is equivalent to one Imperial gallon of gasoline (about 140 cu. ft. per U. S. gallon). The economics of gas operation rest on the price of gasoline and taxes on fuel.

Comment by another English engineer (19) on this subject states: "The experience gained at Mogden and elsewhere has been sufficiently wide and extensive to indicate that the operation of vehicle transport on compressed methane gas is perfectly sound and practicable in every way." However, it will not be used for peacetime conditions, especially by outside consumers. The conditions necessary for the suc-

cessful operation of such power usage are outlined.

Another phase of digester gas utilization for vehicle power in wartime Germany is presented by Imhoff (114). The main interest in this contribution lies in the emphasis placed on increasing the available supply of gas by digesting stable manure. The quantity of gas available from the stable manure of one cow is more than 100 times the per capita gas production in municipal treatment plants. The author states that sufficient stable manure is produced annually in Germany to yield the heat equivalent of 4,000,000 U. S. tons of gasoline. This is double the 1934 German importation of oil and gasoline.

With a digestion temperature of about 80° F., proper circulation of the digesting mass to prevent scum accumulation and proper control of the ammonia nitrogen content, the required capacity of a manure digester in pounds of dry solids per cu. ft. volume is only half that of a conventional sewage sludge digester. The residues left after digestion may be used as fertilizer with little appreciable loss of fertilizer constituents over those associated with present methods of manuring land. Designs have been prepared for German farms of sizes having from 4 cows (530 cu. ft gas daily) to a farming village having over 600 cows (85,000 cu. ft. gas daily). Installation diagrams are shown for manure digesters serving 4 and 50 cows.

The author expresses the opinion that there is probably no market for the use of such equipment in America where there is an abundance of oil and gasoline. However, it may be possible that with American genius for mechanization there may be use for such installations in certain farm districts for the generation of electricity for house and farm use rather than for vehicle transport, although Buswell's scheme of digesting farm waste has not found wide application.

Gas Explosions

Another report on the gas explosion at the Monroe, Mich., sewage treatment plant was presented by Jennings (117), and a report on the gas explosion in the roof of the primary digester at the Herkimer, N. Y., treatment plant was presented by Taylor (204). Although four men were working on the roof of this digester at the time of the explosion there were no serious injuries. Contributing causes of this accident were the accumulation of a cold scum blanket due to the loss of the supernatant jet nozzle in the gas dome. The direct cause was an electric lead and bulb lowered through the gas dome.

The Traverse City, Mich., plant also had its gas explosion. Forton (80) reports on this 6-year old accident that severely injured the night operator. On each of the two digesters is a small control house which is ventilated by open windows. Escaping gas accumulated in one of these buildings to the level of the open windows. The gas-air mixture was ignited by an arcing electric switch when the operator pushed a motor starter button located on the wall of the control building. He was severely injured by the force of the explosion.

Doman (64) details precautions taken to minimize danger of injuries, infection, asphyxiation and explosions in repairing the digestion structures at the East Port Chester and Grass Island treatment plants of Greenwich, Conn.

Digester Repair and Cleaning

Holcomb (108) relates how, at the Cortland, N. Y., plant, the gas line leading from a digester sagged enough to become a trap for condensed moisture. This trap caused considerable variation in the gas pressure until the trouble was discovered and remedied by raising the sagged pipe.

Carpenter (53) describes a resourceful method used to remove the accumu-

lation of a heavy deposit of grit and hard grease from the bottom of a digestion tank at the Ithaca, N. Y., sewage treatment plant. The sludge pumps refused to remove this material. It was finally removed by the use of shovels, a hopper, a sand ejector and water supplied by a fire hose.

Garbage Digestion

Babbitt (36) lists and describes the three methods of dual disposal of garbage with sewage, *i.e.* (a) By installing household garbage grinders and discharging the ground material with water into the sewer; (b) by installing central municipally operated garbage grinding stations to which garbage is hauled, ground and dumped into the sewer, or (c) by hauling garbage to the sewer treatment plant, where the garbage is ground and discharged into digestion tanks. The author states that sewers were conceived for service and the more service they can offer, the greater their value to the public. He lists the cities reporting experience with the foregoing methods of garbage disposal, shows the effect on sewers, sewage and digestion.

Due to the increasing use of the household garbage grinder (the first method of disposal in Babbitt's foregoing list), Rudolfs (183) summarizes the effects of ground garbage on the various units involved in sewage treatment and disposal. Experience gained in the digestion of ground garbage alone and in mixtures with sewage solids shows that well ground finer material digests somewhat more rapidly than coarsely ground and is distributed better throughout the sludge. Providing digestion tanks are not overloaded, excessive scum formation may be avoided by thorough mixing, recirculation of supernatant liquor and dilution with sewage. Experiments made with digestion of garbage at Baltimore showed a higher percentage of CO_2 in the digestion gas than normally produced, and abnormal amounts concentrated ammonium bicarbonate were found in the sludge liquor. This large increase in sludge alkalinity was responsible for increased chemical demands; actual practice in some plants digesting mixtures of garbage and sewage solids and chemically dosing same for vacuum filtration confirmed these findings.

The second method of dual disposal listed by Babbitt is in use in St. Louis, Mo. (9). At Marion, Ind., dual disposal was formerly accomplished by mixing the ground garbage with the sewage. According to *The American City* (12) this procedure materially increased the amount of primary sludge to be handled in digestion and increased the organic solutes and colloids carried to the aeration tanks. Backmeyer (37) states that ground garbage can be put into the sludge digesters more profitably by keeping it in a separate well and not mixing it with the sewage flow. The volume of gas (2,600 cu. ft.) produced from one ton of garbage delivered at the plant has the value of one dollar when used as fuel in the gas engines.

Port Huron, Mich., will abandon garbage disposal by hog feeding and resort to the method of dual disposal now practiced at Lansing, Marion and some other plants. According to Drury (68) this city will construct a sewage treatment plant and municipal garbage will be collected and brought to the plant in cans which will be weighed, emptied, washed and put on return trucks. The garbage will be properly ground and separated from undesirable material and pumped to digesters with primary sludge. Digestion gas will be used for power and heating. The total digestion tank volume will be 5 cu. ft. per capita.

Patents

A patent has been issued to Piatt (168) for a device installed in a digestion tank for automatically removing

a supernatant liquor having a minimum solids content.

Sludge Disposal

Snapp (196) described the change in use of dried activated sludge for fuel to its use as a fertilizer base at the Southwest plant in Chicago. Dust hazards and heating of the dried sludge after loading in cars were problems that were solved by (1) altering the drying system to produce a granular rather than a pulverized product; (2) cooling the sludge on ribbon conveyors from about 200° F. to 85° F.; (3) screening the cooled pellets on vibrating screens to remove oversize particles, cellophane, feathers, sticks and other trash, and (4) a railroad car loading system designed for the job. Dusting, which causes both a fire hazard and an abrasive problem to exposed machinery, was further controlled by keeping all equipment under a negative pressure.

The year completed the eighth year of successful operation of the Plainfield, N. J., spray sludge drier. Downes (66) describes its construction and operation as essentially a cylindrical chamber through which is passing a large volume of hot air (as hot as 900° F.), and at the top center of which the sludge is sprayed as a fine mist into the hot air current. The sludge gives up its moisture and falls to the bottom as dry solids, while the vapor and exhaust gases are blown to the chimney. The pulverant sludge can be burned in suspension in the furnace or used as a humus or fertilizer base. Downes emphasizes that it is not economically feasible to dry sludge of less than 10 per cent original solids content, which would exclude the use of this drier at many existing plants unless concentration of sludge was provided. At Plainfield this is accomplished by an alum flotation process. Drying costs per ton of dry solids are about $10.50 at Plainfield. The reported low maintenance cost of the method should arouse more interest in this type of drier than has been evident to date, unless perhaps the cost of fuel is more favorable at Plainfield than in most communities.

An inspection by American engineers of German sewage treatment plants in 1945, as reported by Fischer (77), revealed that utilization of the sludge for fuel and fertilizer was the principal objective in plant operation. This confirms the intimations of Imhoff as made during his visit to this country just prior to the war. Gas produced from sludge was commonly compressed to 200 atmospheres in cylinders holding 350 to 560 cu. ft. for use in motor vehicles.

Pot experiments with primary digested sludges by Lunt (136) lead him to warn that immediate increases in crop yields from its use can hardly be generally expected, and that it is imperative that adequate supplies of potash be provided. He advises application of sludge several months prior to planting to increase the yield of the first crop as well as to reduce the possible health hazard. Supplementary applications of nitrogen are suggested at planting time. His work and conclusions again confirm that primary digested sludge is a soil conditioner and not a balanced plant food of quick yielding properties.

Hubbell (113) described sludge disposal practices at the Detroit plant, which burns raw sludge from an average daily sewage flow of 315 m.g. He questions the usefulness of elutriation under conditions at Detroit where experimental digestion and elutriation tanks with a design capacity for 500,000 persons (about ⅛ of the total plant designed capacity) were provided. Digestion is practiced, however, and is favorably reported. Sludge gas is utilized and the partially digested sludge mixed with raw sludge from the settling tanks forms a satisfactory filter cake which burns well. Disposal of the waste ash is an increas-

ing problem, and its utilization as a raw material in portland cement is being explored.

Genter (86) in a subsequent contributed discussion of this paper takes issue with the reported failure of sludge elutriation and gives ample supporting data to justify a reconsideration of the Detroit conclusion.

During the war a number of military plant installations distributed liquid digested sludge over land areas in the cantonment (158). Full consideration was given to soil perviousness, type of sludge, wind direction, latitude, and the medical aspects. The location of many such plants near extensive tracts of comparatively open uninhabited land favored the practice, at least during the war years. In many municipalities there would be serious objections to disposal of sludge in this manner.

Hicks (104) reviewed the various methods of sludge disposal and the British experiences. The author looks unfavorably to sea disposal except for large cities. The disposal of liquid digested sludge on land is favored if the plant is located near farm lands. The digested sludge is otherwise dried in open drying beds which should have an area of 1 sq. yd. per four persons. Lagooning is not recommended because of the possible contamination of ground water. Pressing has not been very successful, especially with humus or activated sludge. Prior heating under pressure (Porteus process) of the secondary sludge has overcome the difficulties of pressing. In the British Isles the high cost of ferric chloride has prevented the adoption of vacuum filtration.

The disposal of liquor resulting from heat treatment of sludge (Porteus process) is discussed by Lumb (135). The liquor produced by this process is high in organic matter in solution, B.O.D. and organic nitrogen. In Halifax, England, the liquor is disposed of by returning it to incoming sewage. This method of disposal has had no deleterious effect on performance of filtration or aeration units. Prior to discharge to the incoming sewage, the liquor is settled, and it is discharged evenly over the entire day's flow. Experiments on the separate treatment of this liquor by trickling filters gave effluents which could be returned to the sewage flow at higher rates.

Wishart, Jepson and Klein (227) experimented with factors affecting the coagulation and filtration of activated sludge. Ferric chloride was the most efficient coagulant. Activated sludge in good condition required less ferric chloride than sludge in poor condition. Sludge allowed to stand more than a few hours required more coagulant and filtered at a lower rate. Aeration for 1 to 2 hours reduced the amount of ferric chloride required by activated sludge or mixtures of activated and primary sludges. The amount of ferric chloride required could be reduced by elutriation with tap water, sewage effluent acidified to pH 4 to 5, chlorinated sewage effluent or filtrate from vacuum filtration. Densification of activated sludge reduced the amount of ferric chloride required and increased the rate of filtration, but gave a cake with a higher moisture content than a less dense sludge. Shortage of sludge after coagulation for periods longer than ½ hour had an adverse effect on filtration.

The primary excess activated sludge produced in the London County (England) sewage plant is normally barged out to sea, but during the war experiments were made to utilize the activated sludge as fertilizer, according to Vick (212). Vacuum filtration required a dosage of 6 per cent ferric chloride and produced a cake with 80 per cent moisture. Further reduction of the moisture was necessary before use as fertilizer. The filter press cake was slightly drier than vacuum filtered cake, but the labor involved was

greater. Experiments were carried out on dewatering of the activated sludge on sand beds. The main objection to this method was the high sand content of the cake and the amount of labor. To overcome this difficulty, the wet sludge was applied to perforated zinc plates, placed on top of the sand. The sludge drained much more quickly and the labor for removing the sludge was reduced. Porous concrete filters were also tried to dewater the wet sludge, but proved unsatisfactory because solids settled out and formed a gelatinous film on the surface. Partial digestion was tried but the sludge did not settle. It was found that no settling took place until the temperature of the sludge dropped to 75° F. due to convection currents. In a picket fence thickener tank separation of the liquor could be obtained independent of the temperature.

Mechanical Equipment

The first full year of reconversion has seen an enrichment of the literature devoted to mechanical equipment in the sewage works field. THIS JOURNAL (28) continues to devote a portion of its September issue to the presentation by manufacturers of the latest developments in equipment and supplies. The record includes a diversity of equipment, beginning with copper-silicon alloys by the American Brass Co., and concluding with Yeoman's "Package" Aerifier. Mechanical equipment both in sewer construction and in maintenance, and in sewage treatment, is described exhaustively, and in minute detail in some cases, in two manuals of the War Department (217) (216). A report by a Committee of the American Society of Civil Engineers (166) is complete in its details on the status of the art of sewage treatment, and devotes some space to the maintenance of equipment. In an article by Mohlman (148), illustrations of mechanical equipment in sewage treatment are to be found.

In sewer construction there is a staff description of equipment and methods used for jacking a 48-in. sewer for a distance of 75 ft. under a railroad, using hydraulic jacks (17), and another staff article (18) describes the hazards of compressed air construction and equipment, and methods to overcome them through the use of helium-oxygen atmosphere. Bennett (38) presents a description of the most recent types of trenching machines for sewer construction.

A list of tools and equipment used by the Interstate Sanitation Commission is described by Hess (103). The list may be useful as a check against the list of tools and equipment in any sewage treatment plant. Because the mechanical equipment about sewage treatment plants is principally metallic, protection against corrosion is of importance. Kozma (125) describes a system for the cathodic protection of equipment at Rutherford, N. J. For assistance in the maintenance of sewers, two unique pipe locators are described. One by Cranch (59) locates lost vitrified clay pipes and brick and concrete manholes, with the aid of an electrical device used for some time past in water works practice. A staff item (14) describes the use of another type of pipe locator, applicable particularly to the location of house sewers and of laterals, not involving the use of electricity. A unique and effective sewer cleaner, depending on the principles of an expanding cone pushed by water, is described by Loving (133), and the equipment for cleaning 6 miles of sewer by the Belt Railway, of Chicago, is described in a staff article (21).

In the field of equipment for sewer appurtenances Fishbeck (78) discusses various types of sewer regulators, including restricted-dry-weather outlet regulators, leaping weirs, and the Lansing float-actuated mechanical regulator. He emphasizes the fact that no regu-

lator will function without regular and frequent attention. Riddet (177) discusses the design of overflow weirs and compares the formulas used in their design.

Pumps and pumping equipment, including sludge pumping, are covered in articles by Lea (128), Kappe (120), and Daviss (62). Kappe also covers the operation and maintenance of electrical equipment.

Mechanical screens, racks, comminutors, grit chambers and clarifiers are described in articles by Gardner (81), by Darby (61), in a report by a subcommittee of the National Research Council (158), and in a staff article (26). The report by the National Research Council is directed entirely towards military installations, but covers much of the advance and presents a picture of the present status of mechanical equipment for primary sewage treatment. A constant-velocity grit chamber with Parshall flume control is described by Lee and Babbitt (129).

In the field of filtration recirculation of the effluent is attracting attention. Equipment for this purpose is described by Mills (146, 147) and by the subcommittee of the National Research Council (158). A revival of the brush aerator in activated sludge is described by Price and Withnell (172) through an installation at Roch Mills, England.

Methods of heating sludge digesters that are somewhat new are described by Keefer's article (121) on a submerged gas burner, by Rawn's article (174) on the injection of live steam into the digester, and by Langdon's article (127) on heat exchange in an improved circulation tank. The utilization of gas from sludge digesters, particularly in the driving of gas engines, is explained by Burdoin (45) and by Wittwer (230). A fume trap to prevent the passage of exhaust fumes into the engine room is described by Calderwood (48).

The mechanical equipment in the processing of dried sludge at the Southwest plant of the Sanitary District of Chicago is described by Snapp (196), and the improved, vertical, multihearth incinerator at Niagara Falls, N. Y., is described by Smith (195).

Interesting gadgets are described in the literature include Trebler's mechanically driven sampler (208), Lucoff's maxim flow gage (134), and Field's simplified sewer calculator (75).

Industrial Wastes

Industrial wastes have been widely discussed during the past year, particularly at the Second Industrial Wastes Conference held at Purdue University on Jan. 10–11, 1946. Papers dealing with specific wastes were presented by engineers prominent in various industries.

In the general problem of waste disposal, Greeley (91) recommended that industrial wastes be included in sewage treatment programs with some equitable basis for sharing costs, either as a commodity or as a service. In many cases, cities have the right to assess costs, on various bases. Buffalo collected $10,747 in 1945 as excess costs for handling industrial wastes. At Sioux Falls an agreement between the city and a packinghouse was declared void by the State Supreme Court, but an annual license or permit might be issued.

Procedure in California was outlined by Knowlton (124), as chairman of a statewide committee. Many detailed properties of wastes were classified and cost formulae given, as applied at Buffalo, New Brunswick and Anaheim. Effects on sewage treatment plants were noted and relations of waste producers to city or state were discussed.

Siebert (192) in Pennsylvania stated that objectionable characteristics of wastes include excessive volume, grease, yeast, excessive solids, tar, acids, copper and cyanides. Preliminary treatment reduces the harmful effect of such wastes but goes only part way. Within

the plant salvage operations are possible, such as recovery of blood and grease in packinghouses; grains and yeasts in breweries; fiber in paper mills; leaves, stems, skins and hulls in canneries; milk drippings in dairies; distillery slop and chemicals from dye works.

Nance (157) reported that the Irwin Creek activated sludge plant at Charlotte, N. C., was interfered with by wastes. Brewery yeast clogged diffuser plates, increased the ferric chloride dose for sludge filtration and increased the air required. The wastes were removed from the treatment plant and solids recovered at the brewery. Barrel-washing wastes contained grease, which caused further trouble, including production of hydrogen sulfide. The wastes were removed and treated separately. Laundry wastes have also caused trouble.

Le Bosquet (130) summarized the work of the U.S.P.H.S. on industrial wastes in the Ohio River Valley. It was estimated that wastes from 1800 plants in the 204,000 sq. mi. area had a population equivalent of 10 million, of which chemical wastes contributed 1.88 million, paper 1.66 million, distilling 1.0 million, canning 0.76 million and by-products coke 0.745 million. Recovery practices are noted in the brewery, distillery, cannery, meat packing, milk, paper, by-products coke and steel industries, but the actual recoveries are rather meager. Estimates indicate cost of 13.1 million dollars for additional capacity in sewage treatment works due to industrial wastes plus 13.6 million dollars more for treatment of remaining wastes, for which successful methods of treatment or correction are available.

Postwar observations of industrial waste disposal in Germany was described by Gilbert (88). Recovery or treatment plants were built for phenol wastes, pickling liquor, cyanide wastes, chromate and copper wastes. In 1939 there were 65 coke oven plants in the Emscher and Ruhr districts, in half of which phenol was recovered to the extent of 6,570 tons. A new solvent for extraction of phenol called the "phenolsolvan" process is being developed. Copper was recovered by cementation on iron filings. Cyanide was destroyed by lime, chlorine and aeration. Chromates were precipitated by barium chloride and soda ash. Ferrous sulfate was recovered by cooling pickle liquor to 15° C.

Pulp and Paper

Activity of the National Council for Stream Improvement was outlined by Gehm (85). This Council includes 85 per cent of pulp, paper and paperboard manufacturers, and had a budget of $140,000 in 1946, mostly for research. The policy of the Council is to cooperate with state and local authorities and to investigate problems largely by university research. Deinking wastes are being studied by Morgan at Kalamazoo and by Hodge at Mellon Institute. Velz is studying dilution requirements at Manhattan College and Ridenour similar problems at Michigan. Biological studies are under Van Horn at Appleton, also trickling filters under Holderby. Fodder yeast is under investigation at Oregon State College at Corvallis. Strawboard wastes in Indiana are being studied by Bloodgood. At Rutgers, Rudolfs is studying wastes from news and chip board mills, wastes from board mills and rapid biological oxidation of sulfite liquor. University work is also in progress in Maine, Louisiana, Alabama and Texas. It is hoped that continued execution of this program will result in considerable future stream improvement.

A hopeful change in the sulfite pulp process is described by Hatch (99) and Murdock (156), namely the use of magnesia instead of lime for absorption of SO_2, and recovery of the MgO by burning and calcining. Lime reappears as $CaSO_4$ and this cannot be re-used.

The process generates steam as the solid content of the waste liquor is much higher than that of lime sulfite liquor, and only 5 to 10 per cent of the MgO must be supplied. Practically no waste is discharged. The process went into operation at the Weyerhauser plant at Longview in October. Results are awaited.

Disposal of sulfite waste liquor is under small-scale study by Holderby (109) at Appleton and Tyler (210) at the University of Washington. Trickling filters are used. The liquor used by Holderby had a 5-day B.O.D. of 34,000, 13 per cent total solids and pH 2.2 to 2.8. Nitrogen and phosphorous salts were added, and the waste applied to laboratory filters at 3.0 lb. per cu. yd. per day. Sewage or river water was added to bring the solid content down to 0.5 to 1.4 per cent. Recirculation was used, up to 15 volumes. B.O.D. reduction averaged about 65 per cent. Tyler found that the B.O.D. distribution was 11 per cent immediate, 63 per cent due to sugars, 12 per cent acetic acid, 1 per cent alcohol and 13 per cent lignin and furfural. Filters were lucite tubes 2¼ in. in diameter by 5 ft. long. SO_2 was steamed out, oxidized or neutralized before filtration, which was operated at pH values of 3.0 and 7.0. It was possible to operate in the acid range. B.O.D. reduction varied from 50 to 70 per cent. High recirculation, up to 100 volumes, was used. Nitrogen was added; phosphorous considered unnecessary. Results need large-scale confirmation.

Chemical precipitation of paper-mill waste was described by Redlin and Gilbert (175). The plant capacity was 30 tons per day, with 520,000 g.p.d. of wastes. The waste passed through bar screens, then was treated with 24 p.p.m. alum and 12 p.p.m. soda ash, flocculated for 12.5 minutes and settled 3.6 hours. Suspended solids were reduced from 520 to 40 p.p.m. (92 per cent) and B.O.D. from 145 to 14 (90 per cent). Fiber loss was only 0.3 lb. per ton of product. Sludge was discharged to a 1 m.g.d. lagoon, which filled up in 8 months. Another was provided and it was hoped the first would dry out sufficiently for removal of sludge and re-use.

A paper board mill in New Haven (35) reported that 90 per cent of fiber in white water (2.5 lb. per 1,000 gal.) was recovered by use of a Marx conical saveall.

In England the Water Pollution Research Laboratory (198) has studied disposal of paper mill wastes. One mill with 540,000 g.p.d. discharged a waste with a B.O.D. of 230, after some settling. Then coagulants were used, up to 1,800 p.p.m. iron and aluminum salts, to get 75 to 80 per cent B.O.D. reduction. Best results were obtained by alternating double trickling filters. It appears difficult to remove the B.O.D. of these wastes.

Packinghouse and Wool Scouring

Mortenson (153) has studied losses of grease from packinghouse wastes and recommends skimming basins of proper design, with a method of testing the efficiency of such basins. Losses of grease on the surface should not exceed 0.2 lb. per ton kill. Grease basins should receive only actual process waters, not including clear condenser waters, boiler blowdown, paunch contents, hide-cellar drainage or sanitary wastes. Volume may average 2,000 gal. per ton kill. Dry rendering results in greatly decreased losses.

Wastes from wool scouring contain large amounts of lanolin. The recovery of this non-saponifiable fat at Bradford, England (105) has been very profitable. The Esholt sewage treatment work receives wastes from scouring about half the world's wool in sewage from the city, population 263,000. The sewage contains 890 p.p.m. grease and 815 p.p.m. alkalinity in 18 m.g.d. Sulfuric acid is added, the wool fat precipitates into the

sludge, which is heated and filtered, the grease separated, and sold as wool grease or various by-products. In 1945 the income was around $800,000.

Pickling Liquors

Hoak (107) reported the status of pickle liquor disposal. The demand for copperas is only 4.5 per cent of its potential production, hence recovery as copperas is not very attractive. Pickle liquor is still treated with lime in most recovery plants, although research indicates calcium carbonate plus aeration precipitates most of the iron, with lime slurry used to complete the treatment. This process is in use at a steel plant, replacing former precipitation with lime alone. Only high-calcium limestone is satisfactory. The steel industry has no expectation of making a profit from pickle liquor treatment.

Acid iron wastes caused difficulty again at Elyria, Ohio (57). The activated sludge plant received wastes which added 100 p.p.m. iron to the sewage. Although diverted to a quarry, the wastes still gained entrance to the plant and soon clogged the aeration plates. Holes were punched in the plates and aeration now occurs through these holes. New plates are to be installed. The pickle liquor is to be discharged with less acid and neutralized with lime.

Brewery Wastes

The chief chemist of the brewery division, Anheuser-Busch Brewery, B. H. Nissen (159) described the brewing process, salvage operations and disposal of wastes. Spent grains are dried for feed, hops usually used for fuel although sometimes mixed with the grains and dried, and yeast dried and sold as a high-protein food and source of vitamin B. Alkaline wash wastes can be conserved and minimized. Thus wastes are mostly washing and cooling water.

Food Industries

Canning wastes, according to Sanborn (185) are largely solid, such as leaves, stems, vines, skins or hulls. Such solids are 24 per cent of weight of beets, cabbages or tomatoes, 35 per cent of apples and apricots, 40 per cent of asparagus, peaches, pears and spinach, 58 per cent of grapefruit, 79 per cent of peas and 86 per cent of corn. Studies are being made on use for feeds, manufacture of pectin, syrup, oils and waxes. Liquid wastes should be settled after coagulation, following screening. Final treatment is best in lagoons not over 5 ft. deep, with addition of sodium nitrate. A single large lagoon is preferable to several small ones. About two weeks are required for the aerobic plant and animal life to become established.

Solid wastes of many types are being dried at the Eastern Regional Research Laboratory in Philadelphia, as reported by Morris (152). Costs vary from $23 to $36 per ton (dry). A similar product, dried alfalfa meal, of which 860,000 tons were produced in 1944–45, now sells for about $60 per ton. There seems to be a field for development of vegetable drying.

Dairy Wastes

Wilson (222) reported that a plant is being designed to treat 24,000 g.p.d. of creamery wastes at Hillsboro, Kansas. The plant includes two-stage high rate filters, the first filter being 21 ft. in diameter and 6 ft. deep, followed by a settling tank and a secondary filter 17 ft. in diameter and 4 ft. deep. Loading is 7,100 lb. of B.O.D. per acre ft. on the first filter and 2,015 lb. on the second, with recirculation up to 8 times the flow. Wastes contain 200 lb. B.O.D. Results will be of interest, with these heavy loadings.

Synthetic Rubber

Placak and Ruchhoft (169) described experimental results of treatment of synthetic rubber wastes. One large plant, including butadiene and

styrene wastes, had a population equivalent of 474,000 and the 120 m.g.d. of waste an odor concentration factor of 460 volumes. Coagulation was of little value as a method of treatment, also ozone, breakpoint chlorination and activated carbon, in reasonable quantities. Aeration was rather effective, especially if wastes were heated to 50° C. Treatment with sodium sulfite or sulfide and storage for 17 days reduced odor concentration from 8,000 to 250 volumes. Activated sludge treatment of sewage plus 25 per cent of butadiene and styrene waste, and aeration for 24 hr., reduced B.O.D. 90 per cent. Also waste plus sewage (50:50) could be treated on a trickling filter to give 90 per cent B.O.D. reduction, or 86 per cent of undiluted waste, at rates varying from 0.59 to 2.56 m.g.a.d. Influent B.O.D. was around 400 p.p.m.

Petroleum Refining

Hart (98), in a series of papers, discussed the disposal problems of the petroleum industry. These papers include listing state pollution laws, relations of industry and sanitary authorities and types of wastes. These include storage wastes, cracking, reforming and polymerization, and chemical treatment forming alkaline wastes and acid sludge. Emulsions must be broken to prevent loss of oil. Wastes are toxic to fish because of oil, phenol, sulfides, ammonia or alkali.

Morgan, Randolph and Austin (151) described the waste problems of the petroleum industry. Morgan considered the segregation and collection problem, Randolph the salvage of oil and disposal of caustic wastes and Austin the disposal of acid sludge, no longer a waste, by production of coke and SO_2 by the process of the Chemical Construction Company.

Phenol and Gas Works Wastes

The treatment of 75 m.g.d. of wastes at the Dow plant, Midland, Mich., is described by Powers (171). General wastes average 50 m.g.d. and phenolic wastes 25 m.g.d. The general plant wastes are treated by aeration with return of sludge, giving 80 per cent reduction of organic solids, while 25 m.g.d. of phenolic wastes are treated on filters 10 ft. deep, of blast-furnace slag, followed by two activated sludge units, giving removal of 99 per cent of the phenol. The plant cost 1.5 million dollars.

A British committee (116) has reported on the treatment of gas works liquor. Removal of ammonia is necessary, followed by extraction of phenol and final treatment with sewage. Agreements should be reached with local authorities for final disposal. Methods of gas purification should be used which give as complete as possible removal of tar, reduce thiocyanate and sulfides and discharge a uniform effluent.

Cyanide, Electroplating and Metals

Herda (101) described the treatment of cyanide and chromate wastes at Willow Run, Mich. About 300,000 g.p.d. of wastes are treated with sulfuric acid in closed, air-tight tanks, and vigorously aerated to blow out the highly diluted HCN, with discharge through stacks 40 ft. high. Chromates are reduced to the sulfate with ferrous sulfate and precipitated with lime.

Oeming (160) described the treatment of electroplating wastes and listed the various methods that might be used, preferring use of 2 to 3 lb. Cl_2 per lb. of CN at 11.5 pH, and precipitation of chromium.

Ehlen (69) presented considerable information on plating wastes, including processes, analyses of wastes, losses and recoveries.

Grindley (95), in England, experimented with methods for removing chromates. Reduction with copperas and precipitation with lime was satisfactory. In an acid solution 16 grams of copperas were required to reduce

1 gm. of chromium. The method is cheap, and works on both acid and alkaline wastes. Ion-exchange removed chromium but the resin could not be regenerated. Witherite, a natural barium carbonate was used to precipitate chromates. Complete removal of chromium was obtained, but a large excess of the witherite was needed.

Rudgal (182) reported on the toxic effect of copper wastes in the Kenosha sewage on sludge digestion. Small amounts present in the sewage precipitate and concentrate in the sludge. Large concentrations inhibit gas production.

Stream Pollution

Abatement and Control

The technical literature for 1946 has indicated an increasing tempo in the discussion of stream pollution problems. Wolman (231), quoting former President Roosevelt's statement to the effect "that America has managed to mismanage all of its river systems," suggests that this certainly applies with few exceptions to the problem of stream pollution abatement. He points out that the pollution prevailing in many important streams has been studied and restudied and that a comprehensive mass of technical data thereon has been submitted to Congress over the past 10-year period. These data indicate that progress is slow and that between two and three billion dollars must be spent for necessary major corrections of the present pollution conditions.

Hoskins (111) has pointed out that industrial wastes contributed to our streams are equivalent to the raw domestic sewage from 55 to 60 million people and represent a one-third increase over the total domestic sewage contribution. There has been considerable discussion of this tremendous industrial waste pollution abatement problem by a number of investigators. According to Tarman (201) the specialized problems introduced by treatment of industrial wastes has caused abatement of this pollution to lag behind, and has produced a menace to public water supplies, damage to stream waters for industrial use, destruction of fish and aquatic life and loss of streams for recreational use. Todd (205), on the basis of years of experience in the production of drinking water at Wheeling, W. Va., considers the present condition in the Ohio River as intolerable for the production of a palatable water supply with modern methods of water purification. Adams (2) discussed the pollution in the lower Ohio River caused by the discharge of wastes by war-stimulated industries, and proposed a method for the removal of alpha TNT contained in the raw Ohio water. Morgan (150) estimated that industrial wastes equivalent to a sewered population of 860,000 and 2,146 tons of acid per day from mine drainage and discharged in the southwestern Pennsylvania watershed. An additional 44 tons of acid are discharged from metallurgical mills. It is estimated that 1,000,000 tons of waste coal culm are discharged into the Schuylkill River yearly. A program which will cost $6,000,000 to dredge the river and prevent further discharge of coal fines into the river is described by Allen (4). At Toronto, Howard (112) reported that the discharge of wastes has resulted in changes in the mineral composition 10 miles from shore; the chloride content was increased from 7 to 16 p.p.m. since 1911, and phenolic tastes and odors occur in the water supply. The problem of the pollution of fresh water by oil field brines was discussed by Jones (119); and Robinson (181) discussed pollution from gas, coke, tar and petroleum wastes. In a series of papers, Hart (98) discussed the disposal problems, and the effects of the discharge of petroleum refinery wastes upon the receiving streams. The various wastes contributed by the industry are classified and it is pointed out that some of

these are highly toxic to the flora and fauna of streams. Hart suggests that if provision had been made for the installation of waste treatment equipment before the streams became polluted the cost could have been met by the expanding industry. Now costly plants will be necessary for waste treatment. Federal laws relating to wastes from oil refineries are administered by the Army Engineers and the Coast Guard. The plating industry, according to Oeming (161) discharges wastes containing CrO_3, ZN $(CN)_2$, CuCN and acids, and contributes to the stream pollution problems. Cyanide wastes in concentrations of 0.1 p.p.m. are not tolerated by fish. The pollution of the Ohio River and the resulting taste and odor problems on water supplies from the discharge of butadiene, styrene and copolymer wastes by the new synthetic rubber industry were discussed by Placak and Ruchhoft (169).

The use of modern methods of analysis in determining the degree of responsibility of municipalities and industry for pollution was discussed by Gehm (82) (85), who also pointed out that the National Council for Stream Improvement of the Pulp and Paper Industry has an annual research budget of $150,000, which is supported by 75 per cent of the industry. The research and stream improvement program of the Council has been described by Winget (225) and Gehm (83) (84), and includes studies on sludge deposits in rivers, strawboard wastes and deinking wastes. A new pulping process using magnesium base chemicals was described (11), which permits treatment of spent liquors and reduces stream pollution.

The program and plans for pollution abatement by the states was reviewed briefly by each of the state sanitary engineers in *Sewage Works Engineering* (25). The plans to abate the pollution of New York Harbor as described by Gould (90) include construction of plants at 17 different points with a capacity of 1,453 m.g.d. The capital cost of this program is $107,864,000 and it is to be completed by 1950. Kennison (122) stated that, as the dissolved oxygen content of the waters of Boston Harbor has never fallen below 50 per cent of saturation, a high degree of purification of Boston sewage is unnecessary. At Utica, N. Y., Sapanara (186) reports construction of intercepting sewers and plans for a sewage treatment plant to abate the pollution of the Mohawk River. A Mohawk Valley Sanitation Council (22) was formed with two representatives from municipalities, industry, health officials, conservation officials, Federal agencies and the Mohawk Valley Towns Association. The State legislature was called upon to strengthen the conservation laws and provide funds to study the conservation aspects of pollution.

The Sanitary Water Board of Pennsylvania, according to Moses (154) has issued orders to 508 communities and 352 industries to prepare plans for treatment of their wastes. Approximately 365 communities have retained engineering services to this end. Because of a suit brought by the State of Illinois, $17,000,000 will be spent by Indiana municipalities and 20 industrial firms to abate pollution in the south end of Lake Michigan (30). The State Sanitary Water Board of Illinois (29) ordered the city of Mendota to discontinue the discharge of wastes from its sewage system which would result in pollution of the little Vermillion River. This is one of the first orders issued against a municipality that already has adequate sewage treatment facilities but has been negligent in their operation.

The stream control law of Louisiana, which provides for prevention and prohibition of harmful pollution with respect to public health, destruction of fish life, wild or domestic animals or fowls or aquatic life, was described by Cusache (60). The Louisiana Stream

Control Commission is a fact-finding as well as a regulatory body.

Young (233), in discussing pollution control problems, pointed out that cooperation and coordination between the several States in the Ohio River Valley is required, and suggested that Pennsylvania's ratification of the Ohio River Valley Sanitation Compact is a step toward that end. He recommended that the cleanup program should be carried out primarily to improve streams from the water supply standpoint and listed corrective control measures in the following order of importance: (1) adequate treatment of sewage, (2) better controls over taste and odor producing waters, (3) better controls over discharge of industrial wastes causing water treatment difficulties, (4) mine-sealing, (5) flow augmentation with emphasis on those reservoirs best fitting into pollution control programs, and (6) the treatment of other industrial wastes. The Ohio River compact, which was approved by Congress in 1940, and provides for three commissioners from each state and three from the Federal government, was discussed by Waring (218).

The many uses of surface waters and the many interests involved in determining satisfactory stream conditions in the TVA were discussed by Scott (190). The TVA hopes to establish well-rounded programs of cooperative action in collaboration with all interested states. Such a program is in effect in Tennessee.

The opinions of persons, public organizations, industries and states interested in the bills for the control of water pollution were presented in the hearings (58) held before the Committee on Rivers and Harbors of the House of Representatives on HR–519, HR–587 and HR–4070.

Coordination of pollution control by the U. S. Public Health Service as expressed in HR–4070 (the Spence Bill) was approved by the board of directors of the American Society of Civil Engineers (13). However, this board objected strongly to those sections of the bill which authorize the Federal Security Agency to administer the making of Federal loans and grants-in-aid for the preparation of plans for conconstruction of specific sanitary engineering works or to supervise the design and construction of such works.

As an outcome of the discussion of the Spence Bill (HR–4070) and the Mundt Bill (HR–519) in the Committee on Rivers and Harbors, a new Federal Pollution Control Bill (HR–6024) (32) was drafted in April by request of Committee Chairman Joseph J. Mansfield, which combined several of the features of the two earlier bills. The Conference of State Sanitary Engineers of New England (33) immediately went on record as opposing HR–6024 on the ground that it removed the responsibility of state agencies from control of stream pollution matters. A discussion of stream pollution abatement in New England and possible Federal legislation was presented by the various state sanitary engineers (34) which indicated that the consensus of opinion in New England was that Federal assistance and guidance was more desirable than Federal control. The provisions of the above Federal bills, all of which died in the last Congress, and some objections that have been raised to these bills, were reviewed in *Engineering News-Record* (15).

However, without any public hearings, another bill granting powers in the control of pollution was passed by Congress and became public law 732 (173). This law is an act to amend the Act of March 10, 1934, entitled: "An Act to promote the conservation of wildlife, fish, and game and for other purposes." Section two of public law 732 provides that whenever the waters of any stream or other body of water are to be impounded, diverted or controlled, the Fish and Wildlife Service and the head of the state agency having administration over wildlife must

be consulted with a view to preventing loss of wildlife resources. The reports and investigations conducted by the Fish and Wildlife Service and by the state agency concerned, for the purpose of determining possible damage, and means and measures to be adopted to prevent loss of wildlife resources, shall be a part of the report of the government agency responsible for engineering surveys and construction projects. All costs of planning for and construction of the "means and measures" shall constitute an integral part of the cost of the project. Section 5 of this law authorizes the Secretary of the Interior, through the Fish and Wildlife Service and the Bureau of Mines, to make investigations to determine the effects of domestic sewage, mine, petroleum and industrial wastes, erosion, silt and other polluting substances on wildlife and to make reports and recommendations to Congress for alleviating dangerous and undesirable effects of pollution. The investigations include the determination of standards of water quality for the maintenance of wildlife, the study of methods of abating and preventing pollution and the collation and distribution of data on the progress and results of the investigations. The law defines wildlife and wildlife resources as including birds, fishes, mammals, and all other classes of wildlife, and all types of aquatic and land vegetation upon which wildlife is dependent.

Bacteriology and Biology

The problem of distinguishing between the fecal and nonfecal types of coliform organisms was studied by Meerseman (143). This problem is difficult because of the diversity of types found in feces, soil and water, with the resulting difficulty of defining with certainty the characteristics of a purely fecal or nonfecal type. Meerseman pointed out that a sample of water may contain coliforms of several different types and consequently the study of a single isolated strain does not give the desired certainty. Therefore the qualitative study of coliforms cannot be interpreted with mathematical accuracy. However, he considers such a study as an improvement over the purely quantitative index method in general use.

Philson (167) reported a study of the confirmation of presumptive tests for coliforms in brilliant green bile, formate ricinoleate, fuchsine and crystal violet broth, which showed a wide variation of results with these media. Brilliant green lactose bile broth was found to be the most highly selective of the media tested.

Allen, Blezard and Wheatland (5) reported that some chlorinated sewage effluents are highly toxic to rainbow trout, even though the chlorine dose is well below the chlorine demand. They found that if thiocyanate was present, the chlorine reacted with it, forming a much more toxic compound than free chlorine. The toxicity to rainbow trout and minnows of substances known to be discharged to streams in industrial wastes was studied by Grindley (94). He found that $NaAsO_2$ was more toxic than Na_2HAsO_4. Sodium dinitrophenolate was more toxic than sodium picrate, but both had limiting concentrations of about 30 p.p.m. Zinc sulfate at 25 p.p.m. of Zn killed rainbow trout in 133 minutes. About 20 p.p.m. Cr was toxic to trout. The limiting concentration of NH_3 was about 100 p.p.m. A general review of the relation of sewage and industrial wastes to the aquatic life of streams was presented by Ricker (176).

Chemistry

An ether extraction procedure followed by comparison with gelatin kerosene standards for the determination of petroleum products in polluted waters was described by Lurè and Shcherbakov (138). Bezel (39) reported that ceric sulfate is superior to $KMnO_4$ for determining oxidizable matter present in water. This is due in part to the greater stability of the ceric

sulfate reagent together with the stability of its titer. Lurè (137) developed a method for the determination of small quantities of thiocyanates in waste waters based upon a preliminary separation of CNS together with Cl and CN by $AgNO_3$, purification of the residue, decomposition of the silver salts and colorimetric determination of CNS in the form of the complex salt with Cu and pyridine. This method is very accurate. McLean and Speas (141) reported on a preliminary study of fluorescence as an indicator of fecal pollution in waters, and suggested that this method might be useful in detecting only heavily polluted waters.

Stream Aeration

Tyler (209) discussed pollution abatement in streams by direct aeration at points where oxygen deficiencies exist. Results from full-scale tests suggest that the system has advantages in the ability to treat wastes where no very satisfactory treatment system exists, such as sulfite wastes, and in the possibility of immediate stream rehabilitation where sludge deposits are a contributing factor. Inkster (115) presented a mathematical formulation on oxygen balance based on the work of Fair, Streeter and other American workers.

Stream Standards

The Interstate Sanitation Commission of New York, New Jersey and Connecticut (116A) has divided its waters into two classes: (a) those used for shellfish culture, fish life or for recreational purposes and (b) the inner harbor waters not used for the purposes in (a). When waters are to be used for the purposes in (a) the pollution must be treated to have 60 per cent of the suspended solids removed, the coliform organism index must be no more than 1 per ml. in 50 per cent of the samples, and the dissolved oxygen in the vicinity of the outfall shall not be less than 50 per cent of saturation during any week of the year. In industrial area waters (b) the standards are much more lenient and require a removal of only 10 per cent of the suspended solids and a reduction in oxygen demand so that the dissolved oxygen in the vicinity of the outfall shall not be less than 30 per cent of saturation.

Four water quality standards designated A, B, C and D have been adopted for all sections of the Potomac River basin (16). Class A waters are defined as those which can be used for municipal supplies without other treatment than chlorination, and less than 5 per cent of the entire basin is believed to be equal to this standard.

The standards for stream pollution control issued by the Indiana Pollution Control Board (31) prohibit the discharge of floating materials including grease and oil, suspended materials that form putrescent sludge banks, or any materials in sufficient concentration to affect adversely public health, fish life, fur-bearing or domestic animals or plant life. In general the dissolved oxygen content of the receiving water shall be no less than 50 per cent of saturation.

Surveys

According to Chubb and Merkel (55) the acid mine drainage lowers the pH of the Schuylkill River to the point where little biochemical oxidation takes place. Consequently the dissolved oxygen rises until the alkaline waters of Maiden Creek neutralize the acid condition. From this point on, the dissolved oxygen steadily drops as biochemical oxidation proceeds normally. A survey of the Willamette River and its tributaries by Merryfield and Wilmot (144) indicated that the zone of pollution has progressed upstream since the 1929 survey. The pollution is serious from Portland upstream to Salem, and remedial measures should be taken.

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Industrial Wastes

THE HYPOCHLORITE PROCESS FOR TREATMENT OF WOOL SCOURING WASTES AND FOR RECOVERY OF WOOL GREASE *

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Wool scouring wastes are among the strongest wastes produced by the textile industry and they represent a distinct loss to the manufacturer. Several methods of treating wool scouring wastes are in use but, until recently, no satisfactory process has been known for reducing the pollution load which these wastes impose, or for recovering the valuable wool grease which they contain.

The difficulties involved in the treatment of wool scouring wastes have been recognized for many years, and two pertinent observations on this problem were made at an industrial waste conference (1) in 1930: "More hearts and bank balances have been broken on effluent treatment and grease recovery than on any other problem connected with the wool industry. . . . It is a reflection on the combined sciences of chemistry and engineering that a more successful solution than those methods already in existence has not yet been discovered." These observations, however, should be followed by a significant comment made on this subject (2) in 1925: "If it were an easy problem, it would have been solved years ago."

This report describes the development, after five years of research, of a new chemical process for treating wool scouring wastes. Through its use, the pollution load imposed on the receiving stream can be very materially reduced and a valuable by-product can be recovered. A full scale plant, specifically designed to employ the process, has been in successful operation for more than one year.

Wool Scouring and Wool Scouring Wastes

In order to understand the complexities of this problem, it is necessary to review the origin and characteristics of wool scouring wastes. Raw wool is purchased by the majority of mills in the state in which it is clipped from sheep. Before the raw wool can be processed, it must be washed to remove the adhering dirt, vegetable matter, perspiration, and wool grease. These impurities vary from 30 to 80 per cent of the total weight of the raw wool.

The wool is generally washed in a series of five or more rectangular scouring "bowls," each of 1,500 to 3,000 gal. capacity, known as a scouring train. Mechanical rakes advance the wool through the train in a counter-current direction. Wool passes first through water to remove soluble impurities, then through the scouring solution containing mild alkali and soap, and finally through rinsing water. The temperature of the water in the scouring and rinsing bowls is usually maintained between 115° and 125° F. As the wool leaves each section of the scouring train, it is passed

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through squeeze rolls to remove most of the dirty scouring solution before it enters the cleaner bath in the succeeding bowl.

The character of the liquor which results from scouring wool with alkali and soap approaches that of an emulsion in which the grease, organic matter, and fine solids remain in suspension. The waste is a brown, thickly turbid liquor, usually covered with a greasy scum and containing some settleable mineral solids. It is always alkaline and highly putrescible. In general practice, a part of the scouring liquor is discharged continuously and the scouring train is completely emptied one or more times daily. The volume of wastes produced will be in proportion to the amount of wool scoured, but will vary with the type and efficiency of the scouring process employed. Each pound of wool scoured will usually produce from 1 to 10 gal. of waste.

Wool scouring wastes vary considerably in strength, as shown by Table 1 which reports (3) the average of analyses of more than 100 samples:

TABLE 1.—Character of Wool Scouring Waste (3)
Results in p.p.m.

	Maximum	Minimum	Average
Grease	25,800	3,000	8,650
Suspended solids	30,300	2,400	11,520
Alkalinity	29,400	3,430	6,780
Oxygen consumed (4 hr., 80° F.)	7,400	398	1,830

The corresponding biochemical oxygen demand values are estimated (4) to be approximately three times the above oxygen consumed values. On this basis they are 22,000 p.p.m. maximum, 1,200 p.p.m. minimum and will average 5,500 p.p.m. During 1944 and 1945, analyses of wool scouring wastes from several New England woolen mills (5) showed the 5-day B.O.D. value to range between 5,000 p.p.m. and 6,500 p.p.m.

The high B.O.D. value is a result of the high nitrogen content of scouring wastes. A typical waste (3) may contain approximately 1,000 p.p.m. total nitrogen. The more important compounds of nitrogen present are reported to be (2): protein, urea, uric acid, hippuric acid, allantoin, amino acids, and ammonia.

The wool grease is a protective coating for wool fiber during its growth. For the most part, wool grease is composed of higher alcohols and has the properties of a wax rather than of a grease. Exceedingly wide variations may be found in the grease content of wools, even those of the same grade, but the average grease content of wools scoured in the United States (2) is about 13 per cent.

Treatment of Wool Scouring Wastes

It is apparent that the discharge of untreated wool scouring wastes into streams imposes a pollution load due to the grease, mineral solids, and putrescible organic materials which it contains. Unless ample dilution and adequate dissolved oxygen are available to maintain aerobic conditions, rapid anaerobic decomposition will occur, with the production of objectionable odors. Many methods of treating wool scouring wastes have been attempted, partly through necessity brought on by the pollution problem and partly through the desire to recover valuable wool grease.

At least one-fifth of all the wool produced in the world is reported (6) to be scoured in England in the Bradford area. The industrial waste resulting from the processing of this enormous amount of wool was originally discharged without treatment into the Bradford Beck and its tributaries. Pollution of the stream became so excessive that, during an action against the mills in 1868, the Rivers Pollution Commission was appealed to for advice as to how to deal with the foul state of the river. The Commission

was reported to be "at a loss to know how such cases should be dealt with," and it was argued that "if the most able officers whom the government can select are thus embarrassed, it may readily be believed that local boards are in equal difficulty."

Experimental studies in the treatment of the grease-laden effluents were started at Bradford in 1870, but for many years private enterprise and then the Bradford Corporation failed to discover suitable methods of purification. After early experiments with lime and metallic salts as coagulants, the "acid cracking" process was developed. In 1902, the Bradford Corporation first used this process to treat wool scouring wastes and to extract grease. Despite the fact that many other methods of treatment have been proposed and a few other methods have been adopted since that time, the acid-cracking process has continued to be most extensively used.

There is little published information concerning the full scale treatment of wool scouring wastes in the United States. The acid cracking process has been installed by a few woolen mills in this country, and perhaps five of these installations are known to be in operation. It is reported (2) that, before 1925, two woolen mills were scouring wool by a solvent extraction process and it is believed that the number of mills using this process has not increased since that time. The development of a freezing process, designed to remove a portion of the vegetable matter and grease ahead of the regular scouring operation, was reported in 1925, but in 1936 was described (4) as not applied on a commercial scale.

More recently centrifugal processes have been developed for partially treating scouring wastes by recovering a high grade of wool grease. The number of woolen mills which employ a centrifugal process is not known. Of many other methods proposed (4), none appears to have been placed in plant scale operation in the United States. Acid cracking treatment and centrifugal treatment are the only two processes of wool scouring waste treatment which can be considered to be in general use.

Acid Cracking Treatment

In treating wool scouring wastes by acid cracking, the wastes are collected and cooled, then are "cracked" by adding sulfuric acid to produce a low pH value. Proper control of pH and thorough mixing are necessary for successful operation. When a good separation is obtained, most of the saponifiable grease settles as a sludge, carrying with it the major part of the unsaponifiable grease; the remainder rises to the surface as a scum. After the separation is as complete as possible, the acid liquor between the two layers of grease is withdrawn. The sludge and scum layers are dewatered and the grease is extracted, either by boiling and filter pressing directly, or by drying on sand beds and then heating and filter pressing the cake.

The acid cracking process has been employed by a few woolen mills in the United States for many years. It is not only a highly odorous process, but the effluent produced is still unsatisfactory for discharge to streams. While practically all the grease and suspended solids are removed by this treatment, the effluent is always acid and contains in solution much organic matter which becomes putrescible on neutralization. Experiments have shown that the acid cracked effluent can be further purified by chemical precipitation and by biological treatment, but that either method is expensive.

Centrifugal Treatment

The centrifugal process, as developed in the United States about 1930, combines grease recovery with certain refinements in scouring techniques (5). In this process, liquor is with-

drawn from grease recovery from the first bowl of the scouring train, above the hoppers where the sand and heavy solids collect. The hoppers are cleaned periodically by discharging the solids with a small amount of scouring liquor. The liquor withdrawn for grease recovery is clarified in a centrifuge, then is heated, and the grease is extracted by passage through one or more supercentrifuges. A high grade of neutral grease or lanolin is recovered by this treatment.

A number of woolen mills in the United States have adopted the centrifugal process. It is employed as a method of grease recovery and is not intended as an effluent treatment process. Less than half of the grease content is recovered by this treatment and very little improvement is accomplished in the pollutional characteristics of the scouring liquor. The centrifuge effluent, like that from the acid cracking process, can be further purified either by chemical or biological treatment but, again, either method of treatment is expensive.

The Chlorine Process

In 1925, de Raeve described (7), patented (8), and used in Australia a process for the treatment of wool scouring wastes which was based on an entirely new principle. He was the first to point out that "The persistently emulsified condition of wool scour suds and their resistance to resolution results from the presence therein of gelatinous elements. . . . These products are protective colloids which entangle and hold the grease so that it resists separation."

The process proposed by de Raeve consists essentially of three steps: 1. Adding lime to the fresh wastes, cooling, settling, and discharging the supernatant liquor to a chlorinating tank. 2. Adding gaseous chlorine to the supernatant liquor and then acidifying to release hypochlorous acid. This breaks the emulsion, floats the grease to the surface as a scum, and leaves an effluent which can be neutralized and discharged. 3. Heating and hot filter pressing of the scum to recover the wool grease.

As stream pollution problems became more pressing, the need for an improved method of wool scouring waste treatment was recognized. During 1939 the Fields Point Manufacturing Corporation of Providence, R. I., undertook an investigation of the de Raeve process. Laboratory studies were first made of many samples of wool scouring wastes collected from woolen mills in New England. Pilot plant studies were then conducted at several mills, but the results obtained were far from uniform. Not only did the chlorine process yield good results at times and poor results at other times, but it was found impossible to predict which result would occur. The process seemed to have such merit, however, that several years of research were devoted to a study of the theoretical and practical considerations involved.

By 1943, it appeared that suitable control measures had been developed. In the summer of that year, further studies were made by the Fields Point Manufacturing Corporation in a pilot plant erected for the purpose by the Abbot Worsted Company, at its mill in Forge Village, Mass. During these studies, it was discovered that the scouring waste from this mill could be treated with uniform success by applying chlorine as calcium hypochlorite solution instead of using gaseous chlorine. Based on this new procedure, that is, the substitution of an alkaline chlorine solution for an acid gas, the process was immediately simplified.

Equipment for the pilot plant studies at the Abbot mill included an aeration and mixing unit, three 500-gal. settling tanks, a pressure tank, a plate and frame filter press, and chemical feeding equipment. The operation of this plant indicated that the removal

of approximately 90 per cent of the suspended solids, B.O.D., and grease could be accomplished. The effluent resulting from hypochlorite treatment was clear, slightly yellow in color, and had a pH value between 7 and 8. A distinct advantage of the process was the entire lack of odor.

These results were reviewed by the Fields Point Manufacturing Corporation, Abbot Worsted Company, and by Whitman and Howard, consulting engineers for the latter. After careful consideration the Abbot Worsted Company decided, upon recommendation of its engineers, to build a full scale treatment plant employing the hypochlorite treatment process. Since the stream pollution problem at the Abbot mill was less serious than that existing at many other woolen mills, and since no precedent existed for the adoption of this process, the company should be recognized as being unusually progressive in taking such action.

The Hypochlorite Process

The hypochlorite treatment of wool scouring wastes was soon developed into a well controlled process which provides both an improved effluent and a high degree of grease recovery. In addition to the data obtained at the Abbot pilot plant, further studies have been made at other woolen mills. It has been found that an existing acid cracking plant could be converted to use the hypochlorite process, and the plant was so operated for several months. It has been found also that the scouring wastes from mills which employ centrifugal treatment for recovery of grease can be treated by the hypochlorite process. In fact, all types of wool scouring wastes studied to date have proven amenable to treatment by this process.

The first step in the process is the addition of calcium hypochlorite solution to the waste in a continuous-flow mixing and aerating unit. Calcium hypochlorite reacts immediately with the sodium carbonate and soluble soaps, producing a precipitate of calcium carbonate and insoluble soaps. The wool scouring waste emulsion is rapidly separated into its solid and liquid phases, due to the oxidation of organic matter by the calcium hypochlorite.

The amount of calcium hypochlorite required for accomplishing precipitation and separation is readily determined by physical observation of the treated waste after a very brief reaction period. When the proper hypochlorite dose is applied, large curds of insoluble soaps will be formed. Different forms of calcium hypochlorite will vary in chlorine content, consequently the required dose can best be expressed in terms of chlorine. The amount of chlorine required for treatment will be approximately equivalent to the amount of alkali used in the scouring operation.

From the mixing and aerating unit, the treated waste is discharged to one of three primary settling tanks. The settling tanks are operated on a batch system and each tank provides 8 hours detention. After settling, the clear supernatant liquor is decanted and is discharged directly to the receiving stream or sewer.

The waste remaining after decanting consists of the sludge and scum layers which contain the grease and solids. This liquor is pumped to secondary settling tanks where sulfuric acid is added until the pH value is reduced to between 4.0 and 5.0. Mixing is provided by aeration. The acid releases chlorine from the hypochlorite and, after a detention period of 8 hours, concentrated sludge liquor is produced. Supernatant from secondary settling is decanted and is discharged with the larger volume of primary supernatant.

Sludge from secondary treatment is discharged to a pressure tank where it is heated with steam to a temperature of 190° F. Then steam or air pressure is used to force the heated sludge into plate-and-frame filter presses. Steam

is applied to the presses until 70 to 75 per cent of the grease content of the sludge is removed. The filter cake which remains consists of approximately 15 per cent moisture, 15 per cent grease, and 70 per cent inert material. This filter cake can be disposed of on land where it dries readily and without nuisance.

The grease and water mixture flowing from the pressure is discharged to a series of gravity separating tanks. The thickened grease is concentrated in a final tank where it can be steamed and where it can be treated with mineral acid. The finished grease, light brown in color, contains about 2 per cent moisture and 5 to 10 per cent free fatty acid.

Operating Results

The operation of a waste treatment plant must be evaluated from two points of view, that of the sanitary authorities and that of the manufacturer. It has been pointed out (13) that where the industrial wastes are discharged directly into a stream, public health authorities should require such preliminary treatment as will avoid menaces to health, creation of nuisances, or damage to aquatic life, and will protect recreational facilities. Where industrial wastes are discharged into sewers, it seems equitable to require that the industry pay for the treatment of its wastes on the basis of the volume, solids, and chlorine demand or biochemical oxygen demand load which its waste imposes on the municipal treatment plant. It will be shown that the hypochlorite process for treatment of wool scouring wastes can produce an effluent meeting the sanitary requirements described for wastes discharged directly to streams, and that it can provide an effective method for pretreatment of wastes discharged to municipal sewer systems.

The manufacturer, however, must be concerned with matters of cost, since there are few industrial wastes which can be treated at a profit. While it has been pointed out that the cost of waste treatment is a fair and reasonable part of the cost of production, nevertheless, a manufacturer will seldom install and operate a waste treatment plant unless he is required to do so by pollution authorities or unless he can recover a valuable waste product. Operation of the full scale wool scouring waste treatment plant at the Abbot mill in Forge Village, Mass., has demonstrated that a large proportion of the installation and operation costs can be met by the sale of the wool grease recovered.

Recovery of Wool Grease

Using the hypochlorite process, about 98 per cent of the grease can be removed from the scouring wastes and from 70 to 75 per cent of the grease can be recovered and sold. At present prices, this type of wool grease sells at 11 cents per pound. If a mill scoured only the grades of wool high in grease, the process could be very profitable, indeed. Unfortunately, the chemical dosage is largely determined by the chlorine demand of the scouring waste and not by the grease content. Thus, the chemical requirements for treatment of a scouring waste low in grease are at least as high as the requirements for a waste high in grease, and the chemical costs and operating costs are proportionately higher for grease recovered from scouring wastes low in grease.

In a plant built to employ the hypochlorite process, the fixed charges of interest, depreciation, power and labor will be independent of the type of wool scoured. The chemical costs will be proportionately higher for wastes low in grease than for those high in grease. Conversely, the percentage recovery of grease will be lower from wastes low in grease. The economics of the treatment process can best be illustrated by specific examples:

1. Scouring Wool Low in Grease:
   Grease content of wool, 5.0%.
   Wool scoured per week, 150,000 lb.
   Volume of wastes, 150,000 gal.
   Total chlorine required, 5,000 lb.
   Total acid required, 6,000 lb.
   Wool grease recovered, 5,200 lb.

2. Scouring Wool High in Grease:
   Grease content of wool, 10.0%.
   Wool scoured per week, 150,000 lb.
   Volume of wastes, 150,000 gal.
   Total chlorine required, 5,000 lb.
   Total acid required, 6,000 lb.
   Wool grease recovered, 10,400 lb.

Research is being continued on process improvements, on methods for increasing the percentage recovery of grease, and on other applications of the treatment process.

Stream Pollution Aspects

The full scale plant has operated consistently without odors, producing a clear effluent, slightly yellow in color, and slightly alkaline in reaction. Settleable and suspended solids are completely removed from the wastes, and less than 5 per cent of the grease content remains in the effluent. The removal of B.O.D. varies from 80 to 90 per cent.

Some discussion of the B.O.D. value of these wastes is warranted, however, because the percentage removal figure may be misleading. In general, the B.O.D. of the raw wool scouring wastes is extremely high, ranging from 5,000 p.p.m. to at least 6,500 p.p.m., and the B.O.D. of the treated effluent is about 600 p.p.m. to 700 p.p.m. Since from 20 to 60 per cent of the total nitrogen content of the raw wastes remains in the effluent, and since analyses indicate about half of the free and albuminoid ammonia to remain, the B.O.D. of the effluent appears to be caused by the soluble nitrogen compounds.

It must be taken into consideration also that the determination of B.O.D. of a chlorinated effluent is not an entirely satisfactory procedure. The effluent from the hypochlorite process contains a substantial amount of residual chlorine, generally from 25 to 50 p.p.m. Samples of such effluents must be dechlorinated in order to determine the B.O.D. value, and the results of this determination are not strictly comparable with the lower demand which a chlorinated effluent actually exerts on the receiving stream.

From a practical point of view, it may be considered that the removal of practically all of the suspended solids and grease, and of 80 to 90 per cent of the B.O.D. from an industrial waste represents a very material accomplishment. The present effluent no longer contributes to sludge deposits, decomposing solids, grease, or an excessive oxygen demand. The effect of such treatment has been immediately apparent in the improved appearance of the stream into which the treated wastes are discharged. Fish and other aquatic life have returned to the stream not far below the point at which the effluent enters.

The wool scouring effluent produced by the hypochlorite treatment process would impose no solids load or chlorine demand load if it were discharged to a municipal sewage treatment plant. The actual B.O.D. requirement of such an effluent in a secondary treatment plant would be difficult to evaluate because its chlorine demand has been satisfied and it carries some residual chlorine. Investigations are being made to determine the applicability of biological processes for separate treatment of this type of effluent for installations where specific requirements may require greater reductions in B.O.D. values.

Patent Application Made

Fields Point Manufacturing Corporation, which developed the hypochlorite process for the treatment of wool scouring wastes and for the recovery of wool grease, has made a patent application to cover its use. Rights to use the process and technical assistance are

available to woolen mills where such treatment is applicable.

Acknowledgments

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HYPOCHLORITE TREATMENT OF WOOL SCOURING WASTES —A DISCUSSION

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The paper presented by Mr. Faber does more than describe the development of a new chemical process for treating wool scouring wastes. It suggests that chemical engineering principles, rather than the usual sanitary engineering methods, may be required in order to devise the most suitable treatment for certain types of industrial wastes.

Early failures to solve this problem were perhaps due to the fact that nothing better than the conventional modes of treatment, which were not altogether satisfactory, had been developed. An interesting comment quoted by Mr. Faber sums up the entire situation, "If it were an easy problem, it would have been solved years ago." As a matter of fact, the treatment of wool scouring wastes should have been solved years ago if the original work had been carried to its completion and if its primary objective had been the production of a better effluent.

It is apparent that a different approach was necessary, because treatment of this type of waste required

dosages of thousands rather than hundreds of parts per million. Yet such a chemical dosage can, in reality, be economical when a valuable by-product is recovered. As has been indicated, the treatment process worked out represents painstaking research. This research has not stopped at just a solution to the problem, but is continuing to further developments and refinements in reducing the cost of treatment and in producing a high quality by-product grease.

The first new development concerns scouring and its relationship to the cost of waste treatment. Studies of this factor were conducted first on a laboratory and finally on a plant scale. The results showed quite conclusively that the amount of alkali used in the scouring of wool bears a direct relationship to the amount of hypochlorite used. This is easily understandable when we consider that coagulation or "breaking" of the emulsion comprising this waste takes place at a pH considerably lower than the pH of the reacting chemicals. The reaction is one of double decomposition, and the higher the alkali content of the waste the larger the dose of calcium hypochlorite needed to neutralize it. This important fact not only determines the economics of the waste treatment, but makes possible the production of a uniformly scoured, better wool at lower cost.

The development of this process was destined to answer many of our own questions and to start new trains of thought. As pointed out by Mr. Faber, originally chlorine was tried with inconsistent results, and through complete failure of a plant run that was made using gaseous chlorine, a great many of the answers were obtained. Hypochlorites of all types and combinations were tried on various types of wastes. The data obtained showed that a manufactured liquid calcium hypochlorite would produce consistent and uniform results all the way through. It was subsequently found that certain dry calcium hypochlorites could be used and this fact opened the way to the use of commercially available dry products with comparative success and some advantages.

As is the case in most batch processes, the question of continuous operation is constantly in the mind of the engineers, and this phase of the process has received careful and constant consideration. In Mr. Faber's report on the centrifugal process, he has outlined the system of grease recovery which has many advantages in continuous operation. The hypochlorite process, however, could accomplish an additional advantage in providing a clean and clear effluent, so a combination of the two was tried in the hope of attaining the desired results.

The work was undertaken at the Abbot plant with the intention of producing two types of grease on a continuous basis. The results, while not conclusive, showed that a high grade wool fat was obtainable along with the type of grease produced by the plate and frame filter presses. Continuous operation was possible but required the same type and amount of equipment as used in plants utilizing the centrifugal process. This fact alone forced the abandonment of such a system and spurred our efforts toward improvements to fit the situation, and also toward finding a machine that would lend itself to continuous operation. From this work, however, many of the questions regarding the recovery and quality of grease were answered.

It became apparent that in the centrifugal process a high grade grease with good color was obtainable only with low recovery. This also answered the question as to why the hypochlorite process with a higher recovery was not able to produce a light grease with low fatty acid content. The corroboration of this was furthered by studies on the greased wool. Here it was found that the grease obtained from wool by sol-

vent extraction was light brown in color and contained as high as 10 per cent by weight of free fatty acid (as oleic) and that by separating this grease into its component parts, unsaponifiable and saponifiable portions were obtained. The former, resembling grease from a centrifugal process, was light yellow in color with no fatty acid, while the latter, a medium brown colored grease, resembled the form commonly called degras.

The idea of continuous operation was again tried in the early part of 1946 and a complete study was made of a flotation process employing the Fagergren ore flotation machine. This device can be adapted to float off the greases and solids from wool scouring wastes by violent air agitation. The mechanical scrapers continually skim the greases and solids as they form and the waste is discharged clear and free of solids.

Small scale runs were first carried out at the research laboratories of the American Cyanamid Company and the initial success warranted the making of a specially designed small machine which could treat 10 g.p.m. Several months later, further work was initiated using this machine in conjunction with the hypochlorite process. Using wool scouring wastes from different mills, several complete runs were carried out. The results of the tests were surprisingly satisfactory and, at present, necessary changes in machine design are being made to adapt this equipment to fit the process.

This research may have many practical applications in the future. The cooperation of chemists, manufacturers, and engineers has been of material assistance in the development of the hypochlorite process for the treatment of wool scouring wastes. Their interest has proved that the need exists for a waste treatment process of this type. With such cooperation, rapid advances in stream pollution abatement can be expected.

THE OPERATOR'S CORNER

SIX ELEMENTS OF SAFETY

Generally speaking, every living person must follow certain fundamental rules of safety if he is to protect himself from personal injury, regardless of where he is or of the activity in which he is engaged. It would seem that the word "safety" encompasses in itself the key to these rules:

S = *Saneness*
A = *Alertness*
F = *Foresight*
E = *Equipment*
T = *Teachings*
Y = *YOU*

There are more ways than one to go about a job, some of which are likely to involve personal hazards of more or less degree. The *SANENESS* of one's approach to the task at hand will determine the amount of risk. The safest way is the best way!

ALERTNESS to recognize potential hazards requires no special physical sense. It does entail step by step planning of the job, with visualization of each operation. No more than a little imagination should be necessary to detect possible hazards.

Most accidents can be prevented by *FORESIGHT* in planning the job and circumventing hazardous procedures. Moreover, it is this element that instigates advance preparation for that which may happen unexpectedly. The always ready first-aid kit, the convenient list of emergency telephone numbers, the top-side men on the safety hitch rope, etc., are simple examples.

Foresightedness leads to the procurance and use of the protective *EQUIPMENT* that is necessary to prevent and minimize hazards to working personnel. The proper safety devices are never too expensive; dollars and lives are not cancellable.

In the *TEACHINGS,* or lessons, that come from each accident, there is complete information as to how similar ones can be avoided. There is no excuse for the repetition of accidents that are similar in their causes.

The final and most important element of all is *YOU*, the personal factor. Knowledge and rules do no good if they are not applied. The superintendent must be safety conscious himself if he expects his men to perform their duties without taking risks. Compliance with the requirements of this factor involves constant reminder of all personnel that every hazard is to be respected and circumvented by safe practices.

These are suggested as the cardinal tenets of safety. Try to abide by them —to the letter!

W. H. W.

SALARIES FOR SEWAGE TREATMENT PLANT OPERATORS *

SPECIAL COMMITTEE REPORT
NEW ENGLAND SEWAGE WORKS ASSOCIATION

September, 1946

The original Committee on Operators' Salaries, consisting of Frank L. Flood, Chairman, William J. Snow and Paul V. Fleming, was appointed after the 1940 Annual Meeting of the New England Sewage Works Association. The assignment of the committee was to study the question of appropriate salaries for and improvement in the status of sewage treatment plant operators. The original committee submitted a report in 1942 in which was presented the results of a questionnaire survey of operators' salaries in Connecticut, Massachusetts, New Hampshire and Rhode Island. The original committee recommended the appointment of a permanent Committee on Operators' Salaries to further the interests of plant operators. The following suggestions were offered as a preliminary outline for the work of the suggested permanent committee:

1. An investigation should be made of the workings of other committees and associations with similar aims and ideals.

2. A study should be made of advisable legislation to promote the status of sewage treatment plant operators, including in particular: (a) licensing of operators and (b) tenure of office.

3. The establishment of suitable classifications and step increases in salary should be promoted. The assistance and cooperation of consulting engineers in establishing appropriate salary rates and step increases in pay for operators of plants designed by them should be invited.

4. Vacations with pay and reasonable allowances for sick leave should be sought for all plant operators on the permanent staff.

A permanent committee consisting of Joseph A. Muldoon, Chairman, John H. Brooks and Samuel M. Ellsworth was later appointed by the Executive Committee. This permanent committee was inactive because of the war but nevertheless made a progress report in 1943. Later the membership of the committee was changed to include Thomas R. Camp, in lieu of Samuel M. Ellsworth, deceased. The present committee was appointed for the year 1946 at a meeting of the Executive Committee held on October 26, 1945. A progress report of the present committee was submitted at the Spring Meeting on May 17, 1946.

Classification and Certification

The appointment of the original committee was prompted by complaints which had come to the Association that operators' salaries were too low. The original committee was cognizant of the fact that increases in operators' salaries could not be obtained unless it could be shown that such increases were in the public interest. It was recognized by the committee that salary scales should be based upon the degree of responsibility assumed by the operators and should also be based upon qualifications of operators. The New York state classification of sewage treatment plants was used by the original committee as a basis for its study of salaries.

* Discussion and action on this report is expected to take place at a 1947 meeting of the NESWA. Those wishing to offer comments or criticism may direct communications to Thomas R. Camp, 6 Beacon St., Boston 8, Mass.

Since the report of the original committee was submitted, a study has been made by a special committee of the Federation of Sewage Works Associations on "Qualifications of Sewage Treatment Plant Operators." The final report of this special committee was approved by the Board of Control of the Federation on October 17, 1945 and is published in SEWAGE WORKS JOURNAL, January, 1946 (page 147). This report advocates the certification of operators by state agencies. It is recommended in the report that the certification of sewage treatment plant operators be passed upon by a board consisting of a representative of the state agency having supervision of plant operation, together with a leading educator in sanitary engineering and a leading sewage treatment plant operator.

The above mentioned report is recommended for study and action by all state supervising agencies and for study by all sewage treatment plant operators. The report suggests a classification for operators based upon the size and complexity of plants and also recommends the certification of operators in each class. Extracts from the report relating to classification of operators are quoted herewith:

CLASSIFICATION OF OPERATORS

The term "operator" shall apply to any person having active field supervision of a sewage treatment plant. It shall not apply to a city engineer, public works superintendent or other similar official who exercises only general supervision. Classes for superintendents, based on the size and type of sewage treatment plant to be operated, are recommended.

Chief operators in responsible charge of scheduled shifts at all plants having 24-hour operating supervision, or at all plants serving more than 50,000 population or equivalent sewage flow, should at least possess qualifications for the class below that of the superintendent under whom they serve.

Chief chemists at plants serving more than 50,000 population, or equivalent sewage flow, or at any plant employing activated sludge or chemical precipitation of sewage should be approved as such. Applicants for such a position should possess a college degree in engineering or chemistry, which has included acceptable courses in sanitary science, or other satisfactory educational and practical experience.

Plants should be classed according to population served, or sewage flow handled, and type of plant.

The following is suggested as a method of classification on the basis of population (or equivalent sewage flow) and type of plant.

Class A Plants

1. Plants serving more than 50,000 population.
2. Plants serving 20,000 to 50,000 population, employing activated sludge, separate sludge digestion with gas collection, biological oxidation, chemical precipitation or mechanical dewatering and incineration of sludge, or other highly mechanized or specialized methods of sewage treatment.

Class B Plants

1. Plants serving 20,000 to 50,000 population, not designated as Class A.
2. Plants serving 10,000 to 20,000, employing secondary treatment other than sand filters, separate sludge digestion with gas collection and burning, chemical precipitation, mechanical dewatering or incineration of sludge.
3. Plants serving less than 10,000 employing the activated sludge process, chemical precipitation, separate sludge digestion with gas collection, or mechanical dewatering with incineration of sludge.

Class C Plants

1. Plants serving less than 20,000, not designated as Class B.

The Federation classification is somewhat similar to the New York State classification as outlined in the original report of the committee on salaries. This committee recommends the adoption of the Federation classification by state supervising agencies.

Survey of Operator's Salaries

The present committee has studied the results of the survey made by the original committee, and has made another survey in Connecticut and Massachusetts in order to determine what increases have taken place in operators' salaries in New England during the period from 1941 to 1945. The results of these surveys are shown in Table 1. Each line in the table represents a particular community to which ques-

TABLE 1.—Operators' Annual Salaries in New England Plants in 1941 and 1945

Class A

Superintendent			Operators		
1941	1945	Increase (%)	1941	1945	Increase (%)
$3,700	$4,500	22	$2,150–2,250	$2,700–2,880	27
—	2,750	—	—	2,150	—
2,310	4,212	82	1,720–2,574	2,448–2,552	17
2,581	—	—	1,825–2,226	—	—
—	4,800	—	—	2,250–3,300	—
3,000	3,600	20	1,352–1,716	1,750–2,496	39
1,870	2,666	42	1,750	2,229	28
1,800	2,250	25	1,500	1,775	18
3,500	4,165	19	1,600–1,872	2,236–2,392	33
$2,680	$3,620	35	$1,840	$2,330	27

Class B

Superintendent			Operators		
1941	1945	Increase (%)	1941	1945	Increase (%)
$2,600	—	—	$1,560	—	—
1,820	$2,340	29	1,820	$1,820	0
3,500	3,700	6	1,800–2,750	1,900–2,400	0
—	—	—	1,320	—	—
—	—	—	—	2,300	—
2,080	2,737	31	—	1,850	—
—	—	—	—	2,300–2,900	—
2,600	—	—	1,092	—	—
—	—	—	1,820	—	—
—	—	—	1,560	—	—
2,687	3,150	17	1,900	2,650	40
2,500	—	—	1,570	—	—
—	2,865	—	—	2,043	—
1,768	2,416	37	—	—	—
1,878	—	—	1,409	—	—
1,716	—	—	—	—	—
1,640	—	—	—	—	—
$2,250	$2,860	27	$1,730	$2,200	27

Class C

Superintendent			Operators		
1941	1945	Increase (%)	1941	1945	Increase (%)
$1,800	—	—	—	—	—
1,352	$2,262	67	—	$2,028	—
2,000	2,650	33	—	—	—
1,560	2,642	69	—	2,076	—
1,300	1,930	49	$1,248	—	—
2,000	—	—	1,600	—	—
—	—	—	1,560	—	—
1,320	1,497	13	—	1,380	—
1,280	—	—	—	—	—
1,560	2,280	46	1,248	—	—
1,572	2,329	48	—	—	—
1,456	—	—	—	—	—
1,650	—	—	—	—	—
2,000	3,000	50	1,500	1,755	17
1,404	2,080	48	—	—	—
1,920	—	—	—	—	—
1,378	—	—	—	—	—
1,482	—	—	—	—	—
1,716	—	—	—	—	—
1,640	—	—	—	—	—
$1,600	$2,300	44	$1,430	$1,810	27

tionnaires were sent. It will be noted that data for both 1941 and 1945 were received from some communities, whereas other communities failed to reply on either the first questionnaire or the recent questionnaire.

In analyzing the data the committee has used the Federation classification for operators and has endeavored to select from the returns the salaries of the persons whose duties correspond most nearly to those of the superintendent of the sewage treatment plant, and of the responsible operator of the sewage treatment plant. In the larger plants there are, of course, many other grades between that of operator and superintendent, and also some grades under that of responsible operator. In Class C plants, on the other hand, there may be only one operator who also performs the duties of sewer superintendent.

At the bottom of Table 1 is presented the average salary for each column in the table, together with the per cent increase shown during the period from 1941 to 1945. It will be noted that the average increase ranges from 27 to 44 per cent, with the superintendents of Class A and Class C plants receiving the larger increases. These increases reflect both the increase which might be expected from promotions and increases due to the advance in the cost of living. As will be shown later, the total increase is inadequate.

In view of the fact that a number of large sewage treament plants are under construction or are contemplated in the near future in New England, the committee thought it advisable to consider in its study the salary schedules for large treatment plants in other parts of the country. Information was obtained from The Sanitary District of Chicago, the Minneapolis-St. Paul Sanitary District, the Detroit sewage treatment plant, the Cleveland Division of Sewage Disposal, and from the District of Columbia sewage treatment plant.

Policy in the Appointment of Operators and the Establishment of Salaries

The field of opportunity for sewage treatment plant operators is a relatively narrow one and promotions are limited in individual communities. Modern sewage treatment plants, however, are growing more and more complex and require expert well-trained operators for proper operation. In order to attract competent men to this field of endeavor and to keep them in the field, it is essential that opportunities for promotion and advancement be not restricted. In a single community, particularly a small community, the top salaries that can be paid to operators are obviously limited by the responsibility assumed by the operator. When an operator in such a community reaches this limit it is desirable for both the community and the operator that he have the opportunity to be advanced to a larger responsibility in a larger community. The committee recommends therefore that the standards of qualifications and operators' salaries be made uniform as far as practicable so as to facilitate the promotion of an operator from a smaller community to a larger community.

In many communities the operators have civil service status, either municipal or state. Where municipal civil service is in operation it is not easy for an operator to change from one community to another. In such cases the state supervising agency should endeavor to bring about uniformity in the civil service requirements for operators and flexibility in the operation of the civil service law such as to permit transfers between municipalities.

Basic Salary Scale

Figure 1 shows data compiled from the Bureau of Statistics, U. S. Department of Labor, relating to wage rates and trends in the cost of living. The average wage scale is based on the factory average hourly earnings of a series of groups of manufacturing industries. The purchase value of the "cost of living" dollar is shown by the trends in commodity prices. The commodities included are food, clothing, heat, light and shelter.

The graph extends from 1910 to date in order to include the effects of World War I and the following deflationary period, as well as to show the trends at the present time. Each of our previous major wars, including the War of 1812, the Civil War and the first world war was accompanied by price inflation followed by a longer period of price deflation. Based on past experience it might be expected that the country will have a business depression within the next few years, accompanied by a long period of price deflation. If, however, the federal debt is taken into consideration it will be noted that it is of such great magnitude at the present time that a business depression and deflationary period would be disastrous to our monetary system. It is quite likely therefore that the federal government will endeavor to encourage the continuation of the present inflationary trend in order thereby to reduce the real value of the federal debt. If this follows it is not likely that commodity prices and the average wage scale will be reduced.

It should be noted on the graph also that the drop in the average wage rate during the depression following the first world war was small as compared to the recession in commodity prices. This was doubtless due to some extent to the influence of organized labor. Since organized labor is much stronger now than heretofore it may be expected that wage rates will not recede in the future, even though we have a business depression.

It may be noted from Figure 1 that the cost of living as reflected in the index of commodity prices increased about 35 per cent during the period from 1941 to 1945 and that the average

wage scale increased about 50 per cent in the same period. In the light of this trend the increase in salaries from 1941 to 1945 shown by the survey of New England sewage plants was not adequate. To conform with the increase in the average wage scale throughout the country, sewage works operators should have received an increase of at least 50 per cent. The increase which they actually received, 27 to 44 per cent, reflects not only the change in the cost of living but also salary increases due to promotion.

The hourly wage scale for common labor in the more populous areas of New England exceeds $1.00 at the present time. The committee is of the opinion that even though sewage works operators have some security in tenure which is denied the common laborer, the responsibility which they assume justifies a minimum salary scale at least equal to that of common labor. The committee therefore feels that the minimum wage for responsible operators of Class C plants should be not less than $1.00 per hour or $2,080 per year based on a 40-hour week.

In Table 2 the committee has set up a schedule of minimum salaries for certified operators which should be in force during 1947. This schedule is based upon the minimum wage of $2,080 for responsible operators of Class C plants, with appropriate increases for other classifications. These salaries should apply to new appointees in smaller plants of each class. In larger or more complex plants of each class the minimum salaries should be higher and the present salary paid should take account of promotions and length of service. It should be noted that the recommended salary scale in Table 2 is for the year 1947 only. Salary scales should be modified from year to year to take account of the trend in average wage scales and commodity prices.

Other Considerations

In most of the larger communities, particularly where civil service is

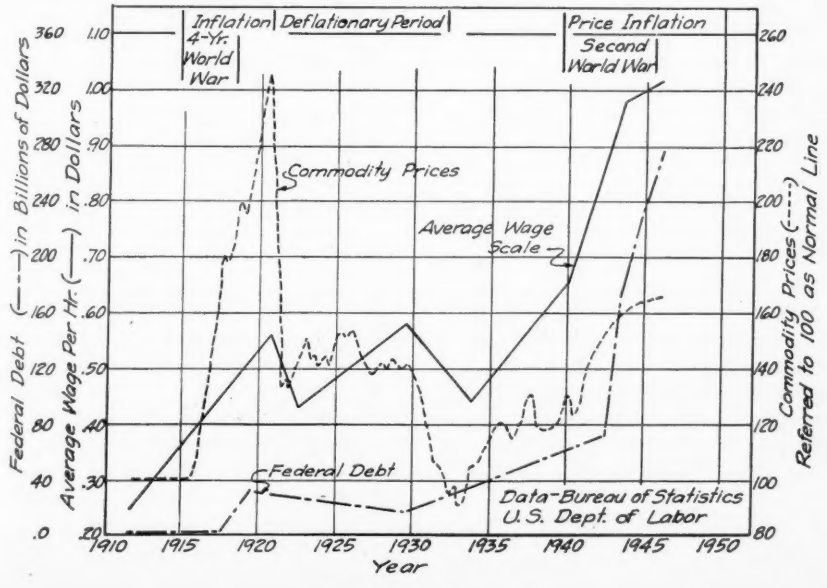

FIGURE 1.

TABLE 2.—Recommended Minimum Salaries for Certified Operators for 1947

Class A		Class B		Class C	
Plant Superintendent	Operator	Plant Superintendent	Operator	Plant Superintendent	Operator
$4,160	$3,120	$3,120	$2,600	$2,600	$2,080

Notes: (1) Minimum salaries apply to new appointees in smaller plants.
(2) Starting salaries in larger plants should be commensurate with additional qualifications and responsibility.
(3) Actual 1947 salaries should be higher than starting salaries by increases allowed by promotion.
(4) Salary scales for years following 1947 should be adjusted to conform to trend in average wage scale and commodity prices.

in operation, provisions are made for step-rate increases or promotions, for vacation and sick leave, for retirement benefits, and in some cases for overtime pay. The smaller communities are somewhat negligent in making such provisions but there has been improvement in this regard. The committee recommends that these matters should receive at least advisory consideration by the proposed state licensing agencies.

Recommendations

The committee recommends that the New England Sewage Works Association support a movement toward certification or licensing of sewage treatment operators throughout New England and preferably throughout the United States as a whole, substantially in accord with the recommendations of the Federation Committee on Qualifications of Sewage Treatment Plant Operators. The committee further recommends that the proposed state certifying agencies should also act in an advisory capacity or otherwise towards the establishment of minimum salary scales for certified operators.

Acknowledgments

The committee wishes to express its appreciation for the cooperation of the treatment plant superintendents who furnished the information required in its work.

Respectfully submitted,
NESWA Committee on Salaries for Sewage Treatment Plant Operators:
THOMAS R. CAMP, *Chairman*
GEORGE H. CRAEMER, *President* (ex officio)
JOHN H. BROOKS
PROF. EDWARD H. BROWN, JR.
JOSEPH FITZGERALD
JOHN SYZMANSKI

A STREAM SAMPLER*

BY MATT KIRN

Superintendent, Waukegan Plant, North Shore (Illinois) Sanitary District

The sampler illustrated in Figure 1 is designed for use with two 250-ml. and one 1,000-ml. bottles, or with any combination of the three bottles that may be desired. It will provide at least a threefold displacement in the bottles of the water or waste being sampled without the entrainment of air bubbles.

This device, with one 250-ml. bottle and one 1-liter bottle, is well adapted to stream survey work, where it is usually desired to use the 250-ml. sample for a field dissolved oxygen determination and the liter sample for B.O.D., suspended solids and other determinations in the laboratory. The sampler is airtight and watertight except for

* This device tied for first prize in the Gadget Contest conducted as part of the 18th Annual Meeting of the Central States Sewage Works Assn., held at Lafayette, Ind., on June 13–14, 1946.

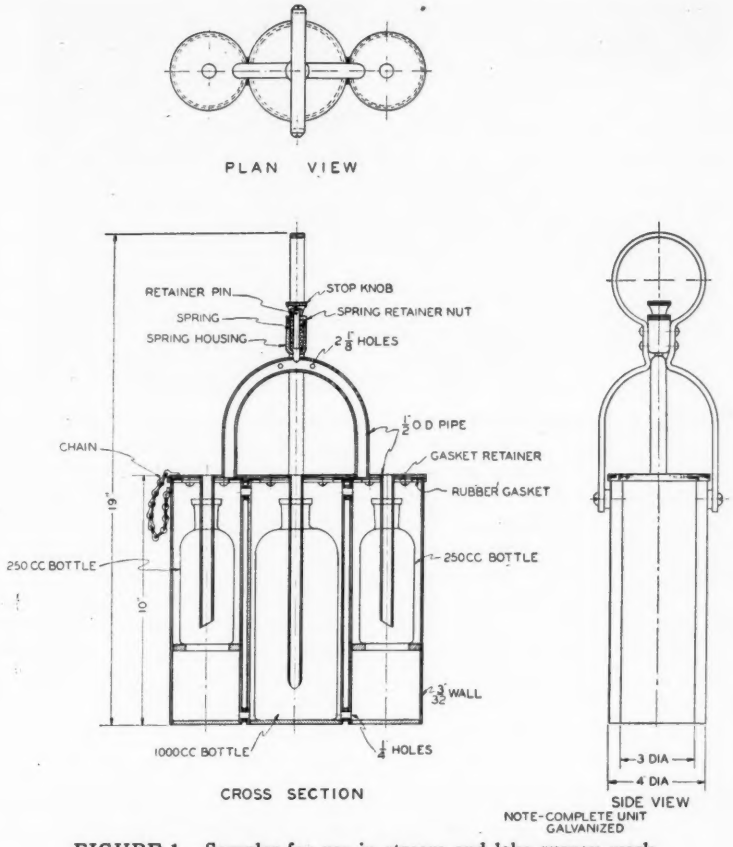

FIGURE 1.—Sampler for use in stream and lake survey work.

the water inlet and air outlet ports.

Chemist Raymond E. Anderson of the North Shore Sanitary District has used the sampler in stream and lake surveys for more than a year and recommends it highly for its scientific construction, sturdiness, convenience and accuracy of uniform sampling.

A DEVICE FOR TESTING GAS ENGINE VALVE SPRINGS *

By Walter A. Sperry

Superintendent, Aurora Sanitary District, Aurora, Illinois

The device described here is used to test the springs on the fuel inlet and exhaust valves located in the valve heads of small gas engines. These springs produce quick and positive closing of the valves. If the tension in them varies more than 10 per cent, engine performance is likely to be un-

* This device tied for first prize in the Gadget Contest conducted as part of the 18th Annual Meeting of the Central States Sewage Works Assn., held at Lafayette, Ind., on June 13–14, 1946.

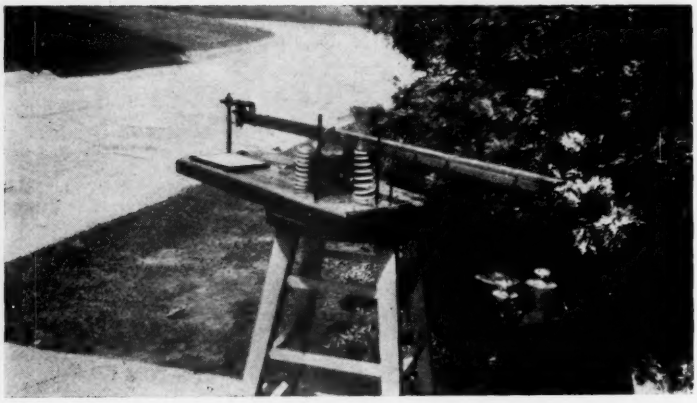

FIGURE 1.—A device for measuring the tension in gas engine valve springs.

satisfactory. After prolonged use some of the valve springs tend to lose their tension and must be replaced.

The tester (Figure 1) is based upon the principal of the second degree lever, resistance being placed between the fulcrum and the effort. The gadget enables one accurately to compare spring tensions so that "matched sets" can be quickly selected. The springs are compared on the basis of one-half inch compression, as determined by observing a pointer against a transparent scale with two hairlines.

The tester is made to accommodate springs of two sizes, and a table of factors is mounted on the base for use in computing the pounds of effort required to compress the spring in accordance with the effort points used for the larger or smaller springs being tested.

EFFECTS OF BEET CANNING WASTES ON SEWAGE TREATMENT PLANT OPERATION *

By Elvey A. Marshall

Superintendent, Sewage Treatment Plant, Geneva, N. Y.

The Gulvin Park Plant at Geneva, N. Y., was designed in 1933 for a normal domestic sewage on the basis of an ultimate population of 24,000 in 1962. In 1935, the year the plant was put into operation, the population was approximately 16,000. The actual contributing population exceeded the engineer's estimate in 1941 and reached a peak in 1942, due to war activities and the influx of large numbers of all types of workers for the construction of the Sampson Naval Base and the Seneca Ordnance Depot in the immediate vicinity of Geneva. At the present time the population is 20,300; this figure closely approximates the designing engineer's estimate. Analyses of the raw sewage made in 1932 and 1933, prior to construction, did not show any abnormalities. Only small amounts of cannery wastes were anticipated, and no significant provision was made for these wastes in the design of the plant.

The plant as designed and constructed is a conventional separate sludge digestion plant. Only primary

* Presented at Spring Meeting, New York State Sewage Works Assn., Utica, N. Y., May 24–25, 1946.

treatment is provided, consisting of a comminutor and three mechanically cleaned clarifiers with provision for pre- and post-chlorination. Two heated digesters and two glass-covered sludge beds complete the treatment facilities, with the exception of the usual raw sewage and sludge pumps. Grit chambers were not constructed, as the treatment of large amounts of cannery wastes containing appreciable quantities of gritty material was unforeseen.

The plant effluent discharges into Seneca Lake at a point 1½ miles west of the lake outlet and 1 mile from a large municipal bathing beach which is well patronized during the summer months. Tests indicated that effective chlorination of the final effluent was necessary throughout the entire bathing season.

Operation in Off-Canning Season

Normal sewage flows of purely domestic sewage are treated without any difficulty during the period from January to September each year. Analyses are made of the amounts of settleable solids, suspended solids, B.O.D., and residual chlorine. The production of gas, both as to quantity and composition during the off-canning season, is considered normal for the average plant.

Operation During Canning Season

The canning season in this region starts in September and continues through to January each year, with beets being the principal product processed. Immediately at the start of the beet canning season there is a sharp variation from a normal domestic sewage, even though the beet wastes as received at the municipal plant have already been screened at the cannery to remove a large portion of the pulp and fiber. This variation is immediately manifested by increased flows and an increase in the gas production, while analyses of the sewage show an increase in settleable and suspended solids content, and a decrease in the moisture and volatile contents of the primary sludge.

The raw sewage has an intense and persistent dark red color, and the chlorine demand is increased greatly over that of the normal domestic flow. One of the main objections to the waste has been the enormous volume of grit that has been carried into the municipal plant.

Increased flows due to beet wash water and other processing water are being handled without any difficulty, because these flows, as far as volume is concerned, still fall within the designed limits of the pumping equipment and the clarifiers. The settleable solids in the plant influent, however, are increased from an average of 12 to about 28 ml. per liter, or about 130 per cent.

Comparative analytical data representing conditions in the off-coming and canning seasons during 1945 are given in Table 1. Percentage removal of suspended solids and B.O.D. are not greatly different in the two periods, but the amounts removed are much higher in the canning season. Although the gas production at the digesters increased about 29 per cent during the canning season, a greater volume was required to maintain the

TABLE 1.—Effect of Beet Canning Wastes on Sewage Works Operation at Geneva, N.Y. —Monthly Average Results in 1945

	Off Canning Season (8 months)	Canning Season (4 months)	Increase (%)
Sewage flow (m.g. per month)	55.01	66.87	21.6
Suspended solids:			
Raw sewage (p.p.m.)	234	360	53.8
Settled sewage (p.p.m.)	42	82	95.3
Removal (%)	82	77	− 6.1
5-Day B.O.D.:			
Raw sewage (p.p.m.)	265	575	117
Settled sewage (p.p.m.)	110	230	109
Removal (%)	59	60	—
Primary sludge:			
Volume (1,000 cu. ft.)	49.21	59.64	21.2
Dry solids (1,000 lb.)	101.01	152.52	51.0
Solids content (%)	3.0	4.3	43.4
Volatile content (%)	73.7	56.2	−23.7
Digested sludge:			
Solids content (%)	10.3	12.8	24.3
Volatile content (%)	44.5	41.4	− 7.0
Gas production (1,000 cu. ft.)	514.88	665.45	29.1
Chlorine applied (lb.)	3,424	4,144	21.0

desired digester temperature. This is due to the lower methane content of the gas when the cannery solids are being digested. The pH of the sludge was lowered by the beet wastes, but not sufficiently to affect the progress of digestion.

Chlorine Demand

A sample of the clarifier effluent during the canning season has the characteristic red color of beets and has no resemblance to domestic sewage. The regular colorimetric method for the residual chlorine test is used but the actual quantitative determination of residual chlorine is quite difficult. The amount of chlorine applied is gradually increased until the point is reached at which the residual chlorine test, when made in the usual manner, will show a bleaching action on the sample when the usual amount of orthotolidine is added.

Samples of the cannery waste, as taken from the effluent line at the cannery, showed a chlorine demand which varied from 220 p.p.m. to 460 p.p.m. These spot tests were made to determine the amount of chlorine required to bleach out completely the red organic color.

The chlorine demand at the sewage treatment plant on spot samples of the beet wastes, after being mixed with the domestic sewage, varied from 5.5 p.p.m. to 20.8 p.p.m.

Bacteriological analyses of samples collected from the plant effluent after chlorination shows a very marked increase in the number of coliform organisms during the beet canning season. From January to September, the effluent shows an average well below the bathing beach standard of 100 *E. Coli* per 100 ml. A maximum of 1,250,000 per 100 ml. has been recorded during the canning season.

Effects of Grit

The biggest problem during the canning period is due to the grit, which is the inorganic material that is washed from the beets at the cannery. The volatile content of the primary sludge decreases about 25 per cent due to excessive amounts of grit. This material settles out in the influent channel to the clarifiers and clogs the sludge line from the primary tanks. It is necessary at times to flush out the cones or sumps in the clarifiers with city water under 80 lb. pressure in order to move the sludge.

The grit is of such quantity that it increases the raw sludge pumping period by 50 per cent at times. In addition, it creates excessive wear at the comminutor, sewage and sludge pumps, and the digester mechanism, thus reducing the normal life expectancy of these units from ten to five years.

The digested sludge must be drawn more frequently in order to keep the discharge lines from the digesters from being clogged, and the sludge drawn has a lower volatile content with an increase in the percentage of solids as drawn to the sludge beds. Here again, it is found necessary to use city water under pressure to dilute the digested sludge and cause it to flow through the discharge lines and troughs on its way to the sludge drying beds. Under normal operations, with 3 to 5 per cent solids in the sludge, it is desirable to avoid the addition of water to the sludge, but in this particular case, with a sludge containing 11 to 12 per cent solids, the unorthodox dilution procedure is required.

Summary

Beet canning wastes have become a problem at the Gulvin Park plant partly because of the lack of adequate preliminary treatment at the cannery. In this particular case, changes have been recommended to the cannery officials that would bring about the removal of a considerable portion of the grit before the cannery wastes are discharged to the public sewer. This,

of course, is a factor which involves the cooperation of the plant officials and makes it necessary for them to operate the cannery in a more efficient manner, by the installation of new equipment and by the employment of dependable personnel. Proper maintenance of vibrating screens would also be advantageous, to minimize the organic content of the wastes as discharged.

The color of the beet waste is a problem because it interferes with the residual chlorine test and, in addition, the waste has such a high demand that the expense of chlorination to decolorize the waste and secure a large bacterial reduction is prohibitive. The waste as discharged into Seneca Lake shows a decided color at the point of discharge but the color is soon dissipated because of the vast amount of dilution in this body of water. Adequate chlorine residuals are not always maintained in the final effluent during the canning season, but this is not considered to create a public health problem since the bathing season ends prior to the beginning of the beet canning season.

The policy of the city of Geneva is to accept industrial wastes to the design limits of the municipal sewage treatment plant, but the industry is expected to bear a reasonable share of the responsibility. With the provision of improved screens and grit removal equipment by the cannery, no difficulty is anticipated in handling the beet wastes in the Gulvin Park plant.

EFFECTS OF BEET CANNERY WASTES—A DISCUSSION

By William A. Ryan

Consulting Chemist, Rochester, N. Y.

Mr. Marshall has covered the subject so thoroughly that there is little to discuss. It may be of interest, however, to investigate the population equivalent of the load on the Gulvin Park plant during the beet canning season.

On the basis of the raw sewage flow and B.O.D. during the off-canning season, the per capita contribution of B.O.D. by the connected population of 20,300 is 0.197 lb. per day. Applying this value to the B.O.D. and volume of the combined sewage and canning wastes gives a population equivalent loading of about 53,500 during the canning season. The beet wastes alone would be equivalent to the domestic sewage load from a population of about 33,000 persons.

Mr. Marshall refers to the action of chlorine in bleaching out the color imparted to the sewage by the beet wastes. The chlorine demand of the combined sewage and beet wastes is so high, however, that it would not be practical from an economic standpoint to remove the color by chlorination.

The ability of a sewage treatment plant to handle successfully a seasonal waste, as from a cannery, depends upon (a) adequate capacity, (b) good equipment and (c) competent operation. The Gulvin Park plant at Geneva has such a combination.

BARK FROM THE DAILY LOG

By W. W. Mathews

Superintendent, Gary (Indiana) Sanitary District

March 5—A certain sign of over confidence on the part of a sewage works superintendent is an urge to undertake an experiment when everything is running smoothly. Today we began a study of air requirements at the activated sludge units, the plan being to step down the blower speed gradually until the disolved oxygen content of the aerated mixed liquor reaches the critical value marking the onset of bulking. The D.O. at the aeration tank outlets is now 5 p.p.m.

We do not intend to carry this too far!

March 14—With the aerated mixed liquor D.O. at 0.4 p.p.m., the activated sludge is beginning to lose its rapid settling properties. This is reflected in the effluent suspended solids value of 23 p.p.m. today, as compared to 1 to 8 p.p.m. at the beginning of the test.

March 15—Test completed. About the middle of the morning the operator on outside duty reported that clouds of sludge were apparent in the No. 2 secondary tank, and an inspection of all units indicated that it was time to boost the air supply.

The blower speed was increased from 236 r.p.m. to 400 r.p.m. and the return sludge rate was increased. The aerated mixed liquor D.O. was 1.4 p.p.m.

March 18—Although the dissolved oxygen at the end of aeration is back to normal (5 p.p.m.), the final effluent suspended solids are still too high.

March 25—With the effluent suspended solids at 6 p.p.m. the activated sludge is now restored to its original prime condition.

An interesting visitor came today and is going to work in the laboratory for about a week. Luis Carlos Alvarez, Consulting Engineer of Bogota, Colombia, South American, and graduate of the Polytechnic Institute in Paris, advises that he has been assigned to design an activated sludge plant to serve part of the city of Bogota. Participating in the "good neighbor" policy, we will give him all the assistance possible.

March 26—Replaced the vent pipe from the hood in the laboratory, the first one having succumbed to sulfuric acid fumes. Also replaced a row of the secondary air filters.

Gary is well known for its picturesque dunes of fine lake sand that add unusual scenic value to otherwise flat terrain. But these dunes are not at all attractive when they are found in a final settling tank, as was the case today when we drained No. 5 to determine the cause of the stoppage of the clarifier mechanism. Built a scaffold and began removal of the sand at once.

Just west of the final tanks are 8 acres of sludge drying beds that were excavated from the natural sand deposit. These have not yet been covered with sludge and the prevailing westerly winds have been quietly engaged in moving the beds into the secondary tanks.

April 2—Off to attend and take part in the program of the Northern Section meeting of the Indiana Sewage Works Operators Assn. The meeting was held at the well kept and carefully operated plant at Marion, Ind., where David P. Backmeyer superintends.

April 3—Back at the plant to find that the crew had finished removal of the sand from No. 5 final tank and had begun to clean No. 2. There are four clarifiers in the west row of secondaries and it appears that all will have to be dewatered for sand removal.

April 4—And away again to Bloomington, Ind. to take part in the program of the Southern Section meeting of the state operators' association.

Disposal of digested sludge in a liquid state was pioneered at Bloomington, where a neighboring farmer hauls the sludge and distributes it over his land with an old-fashioned street sprinkler. Results have been good—at least the farmer thinks so because he has continued use of the sludge in this manner for some time.

The Bloomington plant has also been the subject of some odor complaints and one of the features of the program here was a paper by the city attorney on the legal aspect of sewage works odor nuisances.

April 10—City Manager C. W. Koiner of Pasadena, Calif. called today to look over the plant. Pasadena's activated sludge plant—second oldest in the U. S.—is to be enlarged in the near future.

April 11—Spring is here! The 3-in. hot water building heating line was shut off today.

April 18—The last of the west row of final settling tanks has now been relieved of its wind-borne sand deposit. To prevent a recurrence of this vexatious condition we have fastened a burlap windbreak to the handrails on the west side of these units.

April 21—And another part of this new plant goes into service for the first time as the drying beds receive their first charge of digested sludge. Raw sludge was first pumped to the digesters last August 24—almost exactly 8 months ago. It is safe to predict that withdrawals henceforth will not be at such long intervals!

April 25—With the purchase today of a spanking new power mower we began to canvass the staff for former track athletes. Someone is going to have a full share of hiking to do in herding this gadget about our 10 acres of lawn!

May 1—April was a satisfactory month. From the records nothing out of the ordinary occurred. The treatment process functioned properly and results were good. Gas production was again sufficient for pumping raw sewage and aeration and if this can be maintained at about the present rate it will be worth slightly over $20,000 per year in terms of purchased power. When the engineering report was made prior to design of this plant it was conservatively estimated that gas production would average 1 cu. ft. per capita per day. The actual rate has been about 1.5 cu. ft.

May 3—A disconcerting incident today in the flooding of the meter vault by backwater, resulting in submergence of the transmitter so that the master raw sewage meter was put out of commission. No permanent harm done, however, as a thorough drying out was all that was necessary to restore proper service.

May 7—At the Board meeting today, rules were formulated for the disposition of dried sludge to the public. It was decided that takers would be permitted to remove the sludge directly from the drying beds in their own trucks, they to furnish all tools and labor. No charge is to be made for the sludge.

This practice might not be desirable in most plants because of the excess removal of drying bed sand that would be expected with careless and untrained labor. Loss of sand, however, constitutes no problem at Gary's natural drying beds—which resand themselves automatically.

May 8—Investigation of ground surface settlement south of the as yet unused garbage building revealed that a 12-in. sewer had collapsed and permitted sand to enter the main sewer. Repair presented no serious problem.

May 9—By this time readers of this *Log* will have had about enough of our troubles with sand. Well, so have we, but that did not prevent some of

its getting into one of the ball bearings of the No. 7 agitator, putting the machine completely out of commission. What those pestiferous particles of solid silica did to this bearing was no joke!

A new bearing had to be assembled and installed.

May 17—Time today for a bit of retrospection.

Gas production at the Gary plant has been mentioned several times in this column because of its importance to the sewage treatment field in general and to the Gary plant in particular. The economy possible with sludge gas utilization in activated sludge plants may overcome to a great extent the advantage that trickling filters have enjoyed heretofore in comparison of annual operating costs. Where it is indicated, as at Gary, that it is possible to carry over 80 per cent of the total plant load in horse-power and approximately two thirds in terms of dollars, by utilizing sludge gas as a prime mover, the choice of plant may be decided by this one factor. It is particularly important where a high grade effluent is required as well as freedom from odors.

Considering the Gary plant further, the preliminary engineering report showed that the construction cost of a trickling filter plant would be more but the annual cost would be less than that of an activated sludge plant. It was pointed out at the time, however, that there would be a residential development just south of the plant at some future time, which was estimated to be from 20 to 30 years. The Board, after visiting typical activated sludge and trickling filter plants, decided on the construction of the activated sludge process in spite of the indicated higher annual cost.

That the judgment of the Board was sound is proved by the commencement last year of residential construction in the area adjacent to the plant, this development being at least 20 years in advance of the estimate made in 1938. By the construction of the activated sludge plant the locality is protected from odors that might have resulted from the trickling filters.

May 19—Back water from the Grand Calumet River was discovered running back through the Pierce St. sewer regulator today. Two of the trunk sewers have bulkheads at the outlets to prevent the river from flowing back into the sewers. At this particular sewer the water level must rise about two-thirds the depth of the sewer before flowing to the river. Additional planks were added to the bulkhead.

May 23—Air dried sludge was made available to the public today for the first time. A total of 298 cu. yd. was removed from the beds and the office was busy handling registrations. In order to keep an accurate record of the total quantity removed, each person taking sludge is asked to register name, address and amount desired. Totals are struck monthly.

June 5—Four aeration tanks were taken out of service and replaced by the same number of heretofore unused ones, on account of iron oxide clogging of diffuser tubes. The blower pressure had risen to 8.7 p.s.i. from the original value of 7.0 p.s.i. at the commencement of operation 9 months ago. Waste pickling liquors are the source of the iron.

June 8—A jammed conveyor in the north grit chamber was found to have resulted from a "thrown" wearing shoe. A grit chamber repair is always a mean job, since the stoppage of the equipment is usually not noticed immediately, so that there is usually considerable deposition of grit before the flow can be by-passed. On this occasion the time of four men was required for 6 hours to remove the accumulated grit after the unit was drained. The repair itself was a simple matter.

At this plant a grit chamber breakdown during a storm is most "incon-

venient," since all sewage being pumped must go through the primary treatment units before it can be diverted to the river.

June 10—Cleaning of the diffusers in No. 1 aeration tank is now underway. While hydrochloric acid is usually used for this purpose, we are using a dilute sulfuric—and for good reason. The industry discharging the spent pickling liquor which caused the clogging is donating the cleaning acid!

June 15—With the month half gone we have already been on the receiving end of 7.7 inches of rainfall. Normal rainfall for the entire month is 3.38 inches. As a result, flows have been high and gas production low.

But such ups and downs are all in the day's work in a sewage plant!

SULFUR BACTERIA CAUSE FILTER POOLING *

By Clyde J. Shepherd

Sanitary Engineer, Camp Kilmer, N. J.

The Camp Kilmer sewage treatment plant is of the separate digestion and biofilter type, designed for an average flow of 3.0 m.g.d. (7.5 m.g.d. max.) and a population of 39,000. Completed in October, 1942, the plant has remained continuously in operation since that time, and boasts the unusual record that no raw sewage has been by-passed even though storm flows up to 25 m.g.d. have been received for several hours at a time.

The biofilters, which were the units affected by the sulfide problem described here, are preceded by grit chambers, a mechanically cleaned screen and two circular primary clarifiers. The two biofilter units are 125 ft. in diameter and 3 to 3.5 ft. deep, equipped with Dorr 4-arm distributors providing weir regulated flow. Filter effluent is recirculated to the primary influent from the channel leading to the final settling tanks, of which there are two, and secondary recirculation is provided from the plant effluent measuring flume to the biofilter influent. The effluent is chlorinated at the same flume and the ¾-mile outfall sewer is depended upon as a contact chamber.

* Presented at the 31st Annual Meeting, New Jersey Sewage Works Association, Trenton, N. J., March 20–22, 1946.

The Pooling Problem

During the late winter and early spring of 1944, heavy pooling began to give trouble at the biofilters. At first it was quite easily controlled by prodding or turning over the top stone but this method soon became ineffectual. Other methods of surface treatment were then tried, such as doses of chlorine, bleaching powders and sodium hydroxide. All of these failed to accomplish any degree of benefit.

It was noticed that hydrogen sulfide was discoloring the paint on the buildings. The condition was more noticeable near the supernatant overflow discharge line at the point where it enters the diversion chamber to the primary clarifiers. This observation led to the belief that heavy sulfides were present in the digesters, but many analyses of the sludge and supernatant failed to substantiate this conclusion. Samples of the heavy growth in the biofilters were then examined under the microscope, leading to its identification as *Beggiatoa alba*, a bacteria which oxidizes sulfides.

The problem then resolved to the selection of the best method of getting rid of the growth. Everyone consulted agreed that the first step was to kill all of the growth in the beds. We learned from experience not to do this again.

To destroy the growth, the beds were flooded with clear water from the water supply, at the same time using both chlorinators at full capacity to bring the chlorine residual up as fast as possible. Application was continued until a constant residual of 1 p.p.m. or more was attained. The flooded beds were then left to stand for 48 hr. They were then drained and flushed several times.

The drowned growth was examined under the microscope and it was found that the long stringy strands had for the most part broken up into fine sections and had changed color, indicating that the growth had been killed.

Both filters were treated in this manner. From this point on, it became a process of flooding and flushing to try and slough out the dead matter. Very little progress was made in this way. The thick heavy solids now showed very few or none of the original organisms to be living. Tests were made with all kinds of chemicals in the attempt to induce sloughing but all were unsuccessful. It was getting late in the summer by this time and it was realized that if a new growth were to be developed it would be necessary to take advantage of all the warm weather left. It was then decided to try anaerobic digestion by flooding the beds and letting them stand until all gasification had stopped.

This was done with one filter at a time, which took about 2 weeks each. After this treatment, flooding and flushing was repeated as often as twice daily and often repeated until heavy sloughing stopped. Samples were taken and solids weights recorded. Calculated from these results, it was determined that approximately 3,000 to 3,200 lb. of solids were contained in each bed.

By late September repeated examination of the stone at all depths revealed about 60 per cent of the solids had sloughed out. The beds were then placed into normal operation and new growth started immediately.

In about two weeks heavy natural sloughing was taking place and B.O.D. removals began to improve. By December normal removals were recorded.

Source of Growths

Several competent authorities on sewage treatment were consulted and a number of theories were advanced as to the source of heavy *Beggiatoa* growths that were responsible for the pooling. There has been no definite proof to confirm any of these theories, but the most logical explanation is that leakage into the primary units of ground water of high sulfur content provided a food supply for the bacteria, and that environmental conditions in the filters were otherwise favorable for their development. This conclusion is supported by the fact that the heavy bacterial growths have not recurred since the leaks were discovered and repaired.

It had been noted that unusually large quantities of water were being discharged from the plant underdrains. Analyses showed that considerable sewage was present in the ground water flow, indicating that some or all of the units were leaking, presumably at the expansion joints.

One of the primary clarifiers was drained and measurements of the underdrain flow noted. With one clarifier empty the underdrain discharge had dropped 100 g.p.m. in quantity. As there was a ground water head on the empty clarifier, the water leaking back into the tank had to be pumped out continuously until the ground water level dropped and the flow was down to a minimum. This took about two days and it was noticed that where the water entered at the leaks, a grayish white deposit was left on the concrete. When analyzed, this substance proved to be about 84 per cent sulfur. Since all the surrounding ground was backfill, this allowed for large retaining capacities underground.

Tests showed that the natural soil

was high in sulfur content. This was also proved by other conditions later, wherein cast iron water mains were being attacked by corrosive action wherever these mains rested in ground water. The Camp Kilmer water supply contains only about 35 p.p.m. of sulfates as SO_4.

All leaks at the plant were repaired and, since there has been no return of the sulfides, it is presumed that they were the cause of the pooling condition. During all this time there has never been any change in raw sewage conditions beyond the normal fluctuations in strength.

INTERESTING EXTRACTS FROM OPERATION REPORTS

The more extensive a man's knowledge of what has been done, the greater will be his power of knowing what to do.
—*Disraeli*

Operation Report for Fiscal Year Ended April 30, 1945, Urbana-Champaign (Illinois) Sanitary District *

By W. M. Kunsch, *Engineer-Manager*

Treatment Units

The treatment plant units (Figure 1) include the following: bar screen, Imhoff tanks, sewage and sludge pumps, sludge drying beds, trickling filters, secondary sedimentation tank, effluent lagoon, and secondary sludge pumping. The lagoon is a horse-shoe shaped excavation having an effective volume of about 625,000 gal., surface area of 25,000 sq. ft. and average depth of about 2.5 feet. It was used for final sedimentation until 1929 when the secondary sedimentation tank was installed.

Plant Additions

Following a rather complete study of plant capacity, loadings and requirements for additions, undertaken by former Engineer-Manager Wisely in 1940, additional primary sedimentation and digestion units were designed by Consulting Engineers Greeley and Hansen the following year. A revision of these plans was necessary following decision to include a supernatant selector, heat exchanger, gravity raw sludge drawoff and other minor changes. (*Abst. note:* This plant is one of the first municipal plants, perhaps the first, to install and have in operation at present the relatively new heat exchanger unit for digestion tank heating.)

The most essential units of the proposed additions include a new rectangular sedimentation tank with dual compartments, each 14 by 75 by 10 ft. deep, with capacity of 21,000 cu. ft., and a 45-ft. diameter floating cover digester, with a volume of 35,000 cu. ft. These tanks will be used in parallel with the present Imhoff tanks which have a sedimentation capacity of 33,000 cu. ft. and a digestion capacity of 101,000 cu. ft.

The combination of new and old units will provide for a connected population of 55,000, which is estimated for the year 1960. The present trickling filter capacity is also estimated at 55,000 without undue overloading.

A necessary adjunct to the above mentioned new units will be a sludge pumping station, 20 by 25 ft. in plan, housing a positive displacement raw

* This report earned the Federation's 1946 William D. Hatfield Award, which recognizes the "outstanding sewage works operation report" each year. It is regretted that space limitations make it impossible to present the complete report here. Requests for copies should be addressed to the Urbana-Champaign Sanitary District, Box 18, Urbana, Ill.—*Ed.*

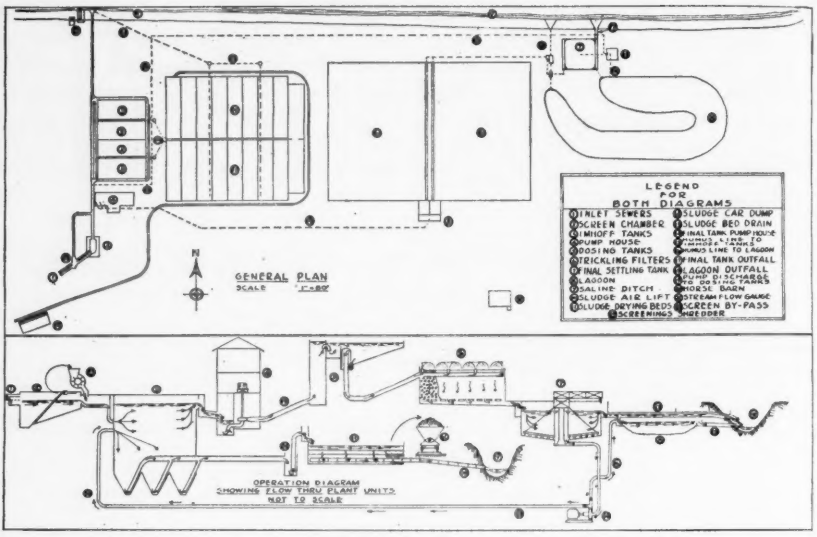

FIGURE 1.

sludge pump, a centrifugal pump for sludge recirculation, sludge meters, gas meters and safety devices and a sludge heat exchanger. The latter eliminates the necessity of having heated coils in the digester. Withdrawal of sludge liquor will be by means of a "supernatant selector."

Imhoff Tanks

Foaming in these tanks began in November and became more pronounced in the following winter months when the scum froze in the gas vents. The rising gas came up into the settling channels, blanketing these also with scum, and disturbing normal sedimentation.

Lagoon

This unit gives added treatment to 40 per cent of the final tank effluent. Following are the removals effected by this unit for the years indicated:

	1944–45	1943–44	1942–43	1940–41
Lb. susp. solids removed per yr.	4,100	25,200	40,000	58,300
Per cent removal—applied susp. sol.	3.5	23.1	33.3	37.5
Lb. B.O.D. removed per year	12,200	21,000	31,100	38,800
Per cent removal—applied B.O.D.	9.4	18.5	25.9	29.6

Judging from the poor removals by the lagoon and from visual inspection of this unit, it is very evident that it must soon be taken out of service for removal of deposited solids. The unit was cleaned during the winter of 1940–41 and has been in service continuously since May, 1941. Comparison of removals for the four years of operation provides an interesting picture of the gradual decrease in effectiveness as the lagoon becomes filled with solids. Four years is apparently the limit of usefulness between cleanings. (*Abst. note:* In the year 1942–43, as an example, the applied suspended solids to the lagoon was 27 p.p.m. and the applied B.O.D. was 27 p.p.m. These relatively weak strengths

make the removals by this lagoon even more impressive.)

Trickling Filters

In the fall of 1944 a test was made of the influence on distribution and discharge volume of increasing the nozzle diameter from 1⅛ to 1$^{3}/_{16}$ inches. This was undertaken because of additional sewage pumping capacity provided by the rebuilding of pumps Nos. 1 and 2. This added capacity made it impossible to use the two pumps together because of insufficient filter nozzle discharge and consequent disruption of dosing tank siphon alternation.

The test showed that distribution of clarified sewage of the filters would not be less efficient with 1$^{3}/_{16}$ inch than with 1⅛ inch nozzle orifices, and from December 5 to 14 reaming of the nozzles was undertaken and completed. This reaming increased the total dosing tank and filter capacity from 6.75 to 7.50 m.g.d., sufficient to permit simultaneous operation of sewage pumps Nos. 1 and 2. The completion of this work in the cold month of December caused a washing out of filter growth resulting in deterioration of effluent for four succeeding months.

Table 1 is a summary of the 1944–45 operating data:

TABLE I.—Summary of 1944-45 Operating Data, Urbana-Champaign (Illinois) Sanitary District

Item	Average
Estimated population	45,000
Total sewage flow (m.g.)	1,259.8
Average daily sewage flow (m.g.)	3.45
Settled sewage by-passed (m.g.)	32.3
Given complete treatment (m.g.)	1,227.5
Reduction in suspended solids (%)*	83.8
Reduction in 5-day B.O.D. (%)*	87.2
Raw sewage:	
Average suspended solids (p.p.m.)	205
Average 5-day B.O.D. (p.p.m.)	263
Population equivalent	42,600
pH	7.5
Imhoff tanks:	
Ave. detention (hrs.)	1.73
Suspended solids removal (%)	53.2
B.O.D. removal (%)	42.9
Sludge loading:	
Lb. dry solids per cu. ft. per mo.	1.06
Lb. vol. dry solids per cu. ft. per mo.	0.85
Ave. digestion temperature (deg. C.)	17
Sludge beds:	
Beds filled	115
Gallons drawn	1,954,000
Lb. dry solids drawn	906,240
Ave. dry solids (%)	5.25
Ave. volatile dry solids (%)	58.0
Loading (lb. per sq. ft. per year)	20.4
Beds cleaned	121
Cu. yds. removed	3,496
Ave. drying time (days)	38.1
Trickling filters:	
M.G.D. applied	3.36
M.G. per acre per day	2.10
B.O.D. loadings applied:	
Lb. per acre per day	2,520
Lb. per acre-ft. per day	252
Lb. per 1000 cu. ft. per day	5.78
Per cent removal—applied susp. solids	47.9
Per cent removal—applied B.O.D.	67.4
Final sedimentation tank:	
M.G.D. applied	3.36
Ave. detention (hrs.)	1.06
Settling rate (gal. per sq. ft. per day)	1,384
Overflow rate (gal. per ft. weir per day)	96,000
Per cent removal—applied susp. solids	42.0
Per cent removal—applied B.O.D.	34.7
Plant operation costs:	
Per m.g. sewage treated	$18.68
Per capita per year	$ 0.53
Per 1,000 lb. B.O.D. removed	$ 9.79
Saline Ditch data:	
Ave. flow (m.g.d.)	21.0
Dissolved oxygen:	
Above (p.p.m.)	6.8
Below (p.p.m.)	6.7
Above (% sat.)	62.7
Below (% sat.)	62.3
5-Day B.O.D. (p.p.m.):	
Above	7.3
Below	9.1

* Adjusted for by-passed primary effluent and 40 per cent flow treatment in lagoon.

Report on the Operation of the Cranston, R. I. Sewage Treatment Works for the Year 1944–45 *

By Walter H. Brown, Jr., *Superintendent*

Manufactured Ferric Chloride Feeder Replaced

The ferric chloride feeders, which have never given satisfactory results, were replaced during the year with a volumetric feeder of original design. This feeder cost approximately $108 to set up. After adjustment, the feeder has reduced the amount of overdose from 85 per cent to about 5 per cent. In other words, the feeder paid for itself in six weeks and, with the present flow, will show an annual saving of about $800.

Industrial Wastes Preclude Activated Sludge Treatment

There has been no change in the operation of the plant during the past year. The heavy industrial load has still prevented operation as an activated sludge plant. The consulting engineers that were engaged to study the industrial waste situation have not made a report as yet, and experiments are still being carried out at the plant under their direction.

Experiments carried out independently have shown that our present brewery and other industrial wastes can be successfully treated to a high degree of purification by the addition of high rate filters between the sedimentation half of the plant and the activated sludge process. No definite statement can be made regarding the Cranston Print Works waste. That would require rather extensive research both at the industry and at the treatment plant, and we are not in a financial position to do that.

It is recommended that the Superintendent be given absolute control over the type and quality of wastes to be discharged into the sewer system. It has been the experience in most other communities, and we are no exception, that this control must be established or very high maintenance and operating costs will result. (*Abst. note:* Worse than this, as has already happened at Cranston, the plant treatment units may fail to function properly.) The activated sludge process may be compared to the operation of a very fine watch—the slighest thing out of the ordinary will upset the works.

Table 2 is a partial summary of operating data for 1945:

TABLE 2.—Summary of 1945 Operating Data at Cranston, R.I.

Item	Average
Estimated population served.....	25,000
Per cent of time plant operating...	98.3
Total sewage flow for year (m.g.)..	346.96
Plant operating cost.....	$26,346.09
Per m.g. sewage treated.....	$75.93

* For last previous extract see: This Journal, **17**, 1, 135 (Jan. 1945).

Annual Report of the City Engineer for the Year Ended June 30, 1944 for the City of Johannesburg, South Africa *

By Dr. E. J. Hamlin, *City Engineer*

Sewage Disposal Works

The bulk of the trade wastes from the Johannesburg municipal area is treated at Antea, Bruma and Klipspruit works. At Cydna works the flow is entirely domestic, while at the Delta works the proportion of trade waste compared with the domestic flow is very small.

* For a previous extract see This Journal, **14**, 4, 897 (July, 1942).

TABLE 3.—Analytical Data from Sewage Works at Johannesburg, South Africa for Year Ended June 30, 1944
(Average of monthly analyses; results in parts per 100,000.)

	Oxygen Absorbed in 3 min.	Chlorine in Chlorides	Oxygen Absorbed in 4 hr.	Settleable Solids (ml./liter, 1 hr.)	Nitrous Nitrogen	Nitric Nitrogen	Ammonia Nitrogen	Albuminoid Nitrogen	Relative Stability (%)	Per Cent Purification—Screened Sewage to Final Effluent	
										On Oxygen Absorbed in 4 hr.	On Albuminoid Nitrogen
Antea Works:											
Screened Sewage	3.75	7.5	12.50	9.4	—	—	5.5	1.90	—	—	—
Tank Effluent	3.04	9.0	9.30	0.6	—	—	6.0	1.30	—	—	—
Primary Effluent	1.18	9.3	2.80	0.6	0.12	1.5	2.7	0.57	—	—	—
Secondary Effluent	0.54	9.2	1.26	tr.	0.13	1.4	1.8	0.24	100.00	89.9	84.7
Bruma Works:											
Screened Sewage	3.61	11.0	10.30	27.1	—	—	5.6	1.96	—	—	—
Tank Effluent No. 1	2.11	11.9	5.30	0.6	—	—	6.5	0.89	—	—	—
Tank Effluent No. 2	2.30	12.3	5.45	0.5	—	—	6.3	1.00	—	—	—
Tank Effluent No. 3	2.32	12.2	6.27	2.1	—	—	6.3	1.09	—	—	—
Primary Influent	1.83	12.8	4.53	1.5	—	—	5.1	1.22	—	—	—
Primary Effluent	1.05	13.1	2.09	0.5	—	—	1.8	0.57	—	—	—
Secondary Effluent	0.59	12.6	1.02	tr.	0.08	2.0	1.0	0.33	100.00	89.2	83.4
Cydna Works:											
Screened Sewage	2.40	6.7	6.60	9.0	—	—	3.9	1.20	—	—	—
Tank Effluent	1.80	7.1	4.00	0.3	—	—	4.1	1.00	—	—	—
Primary Effluent	0.70	7.2	1.50	0.3	0.16	2.6	0.9	0.32	—	—	—
Secondary Effluent	0.46	7.4	0.87	tr.	0.50	2.3	0.8	0.24	100.00	85.2	82.7
Delta Works:											
Screened Sewage	3.83	78.1	9.82	2.2	—	—	6.7	1.88	—	—	—
Tank Effluent	2.63	47.7	6.12	1.3	—	—	6.9	1.29	—	—	—
Primary Effluent	1.31	87.7	2.70	62.6*	0.25	1.0	2.1	0.73	—	—	—
Secondary Effluent	0.63	7.6	1.21	tr.	0.29	1.8	1.4	0.33	100.00	86.6	83.4
Klipspruit Farm:											
Screened Sewage	6.62	15.0	16.66	15.50	—	—	10.71	3.71	—	—	—
Tank Effluent	4.43	14.8	10.56	0.99	—	—	10.50	2.20	—	—	—
Sand Filter	0.60	14.1	1.52	0.04	0.12	1.11	4.10	0.28	100.00	90.55	92.47
Effluent to Homestead Farm	1.11	21.6	2.70	0.68	0.05	0.18	3.81	0.31	68.00	83.49	91.58
Effluent to Harrington Spruit	0.90	21.1	2.40	0.10	0.05	0.29	4.93	0.31	76.5	85.29	91.66
Effluent to Olifantsvlei	0.88	13.9	2.21	0.20	0.17	0.83	5.50	0.31	97.7	86.44	91.45

* Activated sludge rising in separation tanks.

Following is the daily average flow at the various works:

Antea	528,000 gal.
Bruma	2,684,000 gal.
Cydna	1,523,000 gal.
Delta	2,720,000 gal.
Klipspruit	8,667,000 gal.

There has been an increased flow to the Antea, Bruma and Klipspruit works, probably 10 per cent of which is due to industrial expansion. This has made itself felt at these works, and at times the large volumes of oily and other waste liquor reaching them has caused considerable trouble.

No doubt the discharge of harmful liquors and wastes into public sewers is due to ignorance or negligence rather than deliberate wrong doing. If industrialists were to realize the harmful effects on the Council's sewage disposal works resulting from the careless discharge of trade wastes into the sewer system and, moreover, realize that many of such waste matters contain easily recoverable products of commercial value, one feels certain that the present unsatisfactory state of affairs could easily be improved to the mutual advantage of both the Council and industry.

Chemical and Research Work

The pilot plant for the purification of grease recovered from Klipspruit sewage after more than a year of operation was in part incapable of further repair, and the plant was shut down in May, 1944, pending a decision by the City Council concerning the erection of a new and larger plant to deal with all the available crude grease.

The purified "stearic" and "oleic" acids produced in the pilot plant were sold at good prices, and helped to relieve the shortage of these products, especially during 1943.

In December, 1943, the Government Department of Commerce and Industries requested the City Council to cooperate with the department in developing a process for the production of methyl alcohol and formalin solution from sludge digester gas, on the lines of laboratory investigations made previously.

The Council agreed to a capital expenditure of £5,000 for the erection and operation of a commercial scale pilot plant, and the Department of Commerce and Industries undertook to help by providing extra chemical staff and by facilitating provision of materials.

Chiefly because of the wartime difficulty of obtaining materials suitable to stand the high temperature and corrosive conditions in the first high temperature stage of the process, progress in the erection of this plant at the Cydna works has been somewhat slow, but it is hoped that the erection of the high pressure stage will proceed with greater speed.

Table 3 summarizes the laboratory data from the plants.

Fourteenth Annual Report (1945) of the Division of Sewage Disposal, Toledo, Ohio *

By A. H. Niles, *Engineer-Supt.*

Efficiency of Treatment Lower

The removal of suspended solids and B.O.D. has been the poorest in any of the years since the plant has been in operation. The principal reason for this was that one clarifier was out of service throughout the entire year, due to use of the unit for temporary storage of oil and scum removed from the digesters. This operation will necessarily continue until the preaeration and grease removal units, detailed plans

* For a previous extract see: This Journal, 13, 4, 798 (July, 1941).

and specifications for which have been approved, can be constructed. When these units are constructed the efficiency of treatment should improve.

Gas Engine Operation

The gas engine which drives the 36-m.g.d. sewage pump was out of service for 205.5 hours in October for the annual overhaul and then again for 245.25 hours in December. This outage in December was not due to any mechanical difficulty with the engine but rather with the replacement, necessitated by 23 years of continuous service, of a motor-operated valve in the discharge line.

Pumping Station Pump Efficiency Improved

As a result of merely changing the impeller in an electrically driven centrifugal pump at the East Side pumping station, its efficiency has been greatly increased. This new impeller originally cost $1,407.50 in place, and the saving in electric current for pumping during the last six full years, *i.e.*, 1940 to 1945, inclusive, has amounted to $4,580. This is just one small item which stands out in the operating data. (*Abst. note:* Operators of other plants should take particular note of this improvement. There are numerous installations of pumps where efficiency tests have never been made, although the pumps have been in continuous operation for many years. Just because a pump will operate is no evidence that its rate of discharge has not greatly decreased over the years through wear on the impeller and other parts. Replacement of worn parts will frequently be repaid many times over by the saving in electric current, as evidenced by the Toledo experience.)

Sale of Tol-e-Gro

We have had the largest sales of Tol-e-Gro and also the largest profit of any year since we have been selling sewage sludge as fertilizer. We have packaged no Tol-e-Gro in burlap bags for two years; the multiwall paper bag has entirely replaced these unsightly and dirty-to-handle packages. This again proves that the physical appearance of the package is a great factor in selling any product.

Engineering Report for Plant Improvements Rendered

A report has been made by Jones and Henry, consulting engineers, and approval received from the State Department of Health for secondary treat-

TABLE 4.—Summary of 1945 Operating Data at Toledo, Ohio

Item	Average
Sewage flow (m.g.d.)	38.3
Population, design	600,000
Gas production:	
Total produced (million cu. ft.)	105.32
Heating buildings (million cu. ft.)	8.5
Heating digesters (million cu. ft.)	17.4
For sewage pumping (million cu. ft.)	29.9
For engine generator (million cu. ft.)	16.4
Kw.Hrs. generated, total	397,720
Screenings and scum removed (cu. yd.)	3,576
Grit removed (cu. yd.)	851
Digested sludge removed:	
To marsh (cu. yd.)	43,380
To beds (cu. yd.)	14,240
Dried sludge removed from beds (cu. yd.)	2,624
Dried sludge pulverized for fertilizer (tons)	1,152
Tons packaged in burlap bags	None
Tons in 80-lb. paper bags	1,138.6
Tons in 25-lb. paper bags	93.22
Total tonnage sold	1,231.82
Total selling price	$12,576.08
Manufacturing cost	$ 5,001.19
Profit	$ 7,574.89
Chlorine used (total lb.)	242,070
Chlorine used, no. of days in year	66
Digester temperature (deg. F.)	83
Laboratory data:	
Suspended solids:	
Raw (p.p.m.)	218
Effluent (p.p.m.)	99
Per cent removal	54.3
Settleable solids, per cent removal	93.0
5-Day B.O.D.:	
Raw (p.p.m.)	261
Effluent (p.p.m.)	161
Per cent removal	38.5
Total cost of operation	$96,394.60
Cost per m.g.	$6.89

ment for the city of Toledo. This report is quite lengthy and goes into a considerable amount of detail. It is planned, at the present time, to have this report reproduced so as to be available to those individuals interested in the improvement of the Toledo sewage treatment facilities.

Present Plant Facilities and Operating Data

The sewage treatment works consists of two Evers-Sauvage mechanically raked bar screens, two 40-ft. square Dorr detritors, eight 90-ft. by 10-ft. water depth Dorr traction clarifiers, and eight 85-ft. diameter by 29-ft. water depth Dorr digesters, equipped with fixed covers, gas collection and stirring mechanisms. The digested sludge is pumped to the glass enclosed sludge drying beds located a mile from the treatment works proper. These drying beds consist of 4 houses, each containing 12 beds, 20 ft. by 162 ft. The final plant effluent is chlorinated during the summer time for bathing beach protection. The plant was designed for 600,000 population in 1950 with a mean flow of 80 m.g.d.

Table 4 is a summary of the 1945 operating data.

TIPS AND QUIPS

The Quarter-Century Operators' Club, that elite clan of veteran sewage works technicians, has inducted eight new members at and since the Toronto meeting to increase its membership to a total of 27. The recent initiates are Raymond G. Case of Merchantville, N. J. (started at Oaklyn, N. J. in 1921); A. H. Niles of Toledo, Ohio (started at Sturgis, Mich. in 1921); I. H. Nevitt of Toronto, Can. (at Toronto since 1913); Morris M. Cohn of Schenectady, N. Y. (started there in 1921); Wm. A. Ryan of Rochester, N. Y. (operated at Rochester in 1921); Charles C. Agar of Albany, N. Y. (operated at Worcester, Mass. in 1918); E. Sherman Chase of Boston, Mass. (supervised at Reading, Pa. from 1908 to 1913) and Arnold H. Goodman of Chicago (started at Schenectady in 1919).

The Club was given official attention by the Board of Control at Toronto, by the creation of a permanent committee which will maintain the roster and supervise activities. The preparation and issuance of official certificates of membership were also authorized. Frank Woodbury Jones as chairman, with S. E. Coburn and H. W. Streeter comprise the current committee.

It is known that there are many present and former operators who are eligible to membership but who have not yet applied. Information and application blanks may be secured from F. W. Jones 1140 Leader Bldg., Cleveland 14, Ohio.

The new P.F.T. digester heater and heat exchanger in operation at the Urbana and Champaign (Ill.) Sanitary District plant has been the subject of many recent inquiries. This is the first municipal installation of the equipment to go into operation; it is a size No. 1 unit, as described in THIS JOURNAL, **17**, 5, 1109 (September, 1945).

When the new 35,000 cu. ft. separate digester was completed early in 1946, it was filled with sewage and heating was begun on April 15, with a temporary oil burner in use at the heater. By May 17, the temperature of the digester contents had been raised from 52° to 80.5° F., a total of 1,470 gal. of oil having been used.

Since May 17, 1946, the unit has been operating on digester gas, and a temperature of 90° F. has been maintained since June 1. Rather close attention was required during the first

week of operation on gas because of the unstabilized heat value of the gas. There was also some difficulty with the gas valve at first, but this was corrected by replacement of a defective mercoid switch. Satisfactory operation was maintained while the new switch was en route by manual operation of the burner.

It was expected that heat losses from the heater would be sufficient to maintain satisfactory temperatures in the small sludge pumping and digester control building, but in November, 1946 it was found that digester heat requirements did not keep the heater in operation for a sufficient time to furnish enough building heat. One of the two sludge circulating coils in the heater was then by-passed, thus doubling the operating time. The inside of the sludge coils was found to be quite clean when this change was made.

In December, the pilot flame gave minor trouble and a pilot burner having a larger orifice was substituted. This corrected the difficulty but increased fuel requirements quite noticeably.

Delay in securing delivery of certain gas and sludge meters has made it impossible so far to record all of the operating data desired. Gas requirements have been approximately 0.25 to 0.4 cu. ft. per cu. ft. of tank capacity. The temperature differential of the inlet and outlet sludge at the heater is about 2° to 3° F. The water bath temperature has been carried between 145° and 160°; 180° F. is considered the maximum desirable. The sludge recirculating time has been from 4 to 24 hours per day, at various rates.

Engineer-Manager W. M. Kunsch reports general satisfaction with the heater, although he does not consider that operating procedures are at all stabilized as yet. The arrangement is highly flexible and the lack of metering equipment has handicapped trial observations of various operating combinations to date.

Logger W. W. Mathews, who supervises the Gary (Ind.) Sanitary District between entries in his daily log, has found it necessary to shut off the pressure gauges on the air compressor discharges except while readings are taken, on account of the constant pulsation which causes excessive wear on the moving parts of the gauge. A recent news release by the J. A. Campbell Co., 645 East Wardlow Rd., Long Beach 7, Calif., describes the improved "Micro-Bean" pulsation dampener, which may be the solution to the gauge problem at Gary and elsewhere.

The Micro-Bean requires no piston and overcomes the scoring problem by a screw which makes possible maintenance of perfect seating for the dampening plug. The device has found extensive use in aircraft and is recommended for gauge service at boilers, pumps, engines, compressors, etc.

Sludge disposal by burial, as practiced for 14 years at the Mitchell Laithes works of the County Borough of Dewsbury (England), is considered both practical and economical by Manager E. H. Staynes, who describes the method in a pamphlet handed to visiting members of the Northeastern Branch of the Institute of Sewage Purification in June, 1946. More than 800 tons of wet sludge per week is disposed of in this fashion on 22 acres of land. Mr. Staynes' description follows:

"Over a period of 14 years, land was prepared to receive the sludge by digging parallel trenches, a yard wide, two feet deep, with a space of nine feet between, upon which the excavated soil was placed. The trenches, after being filled with sludge, were then covered with the excavated soil. After sufficient time had elapsed new trenches were dug in the space between the original ones and the process repeated. About 30,000 lineal yards of trenches were required for the sludge produced in one year, and the work of digging and covering necessitated the equivalent of the full time employment of six workmen.

"In the main, the system was successful,

it was economical, the cost per ton of wet sludge being 4d (about 8¢), and there was no aerial nuisance. Its disadvantages were that the work of trenching was interrupted during inclement weather, which meant the employment of casual labour, and the almost hopeless task of dealing with the luxuriant growth of noxious weeds which covered the spaces between the trenches."

Supt. L. W. Hunt of the Galesburg (Ill.) Sanitary District mentions the following incident in a recent annual report:

"In October a rather unusual experience occurred while dewatering the secondary settling tank for inspection and painting of the mechanism. When the water level was lowered to within approximately two feet of the bottom it was noticed that the tank appeared to be rising on the east side. Immediate investigation revealed that the swing check valve which permits ground water to enter the tank had failed to open. After relieving the ground water pressure the tank was again filled, which resulted in its lowering to approximately three-fourths of an inch of its former position, and no visible damage resulted."

Which experience indicates two precautions which should be followed in connection with the dewatering of tanks:

1. Be sure that ground water levels are not so high that the buoyant effect will be excessive, and
2. Maintain a constant watch during dewatering, so that the operation may be suspended at the first sign of flotation.

A procedure for rapid inoculation of ponded trickling filters with the water springtail *Achorutes viaticus* comes from Dr. D. Dickinson of the University of Bristol (England), who discussed the treatment of cannery wastes at the December 17, 1946 meeting of the Midland Branch, Institute of Sewage Purification. Dr. Dickinson's method is of particular interest in that an effective inoculation resulted in 17 days.

A quantity of larvae infested filter medium from another plant was scattered lightly over the surface of the affected experimental filter, and enough fresh medium added to give a surface layer ½ in. deep. The filter was then covered with sacking and corrugated iron sheets, and left idle from December 21 to January 7. The *Achorutes* larvae by that time were well established and had considerably reduced the excess surface growths responsible for the ponding.

William T. Ingram, formerly secretary-treasurer of the California Sewage Works Association, has joined the staff of the American Public Health Association as Engineering Field Associate. His new work will involve broadly the stimulation of interest in public health engineering as a profession, with the aim of filling the heavy demand for trained engineering personnel in public health agencies.

The project has been sponsored in APHA by the National Foundation for Infantile Paralysis and by a group of sanitary engineering industries.

Supt. Ben H. Barton of Findlay, Ohio, while addressing the Pennsylvania Sewage Works Association on his experience with dual treatment of garbage with sewage, spoke briefly about the "yield" of metal and other ungrindable items rejected by the Findlay garbage grinder. About 3.3 lb. of such material is recovered from each ton of garbage, although the amount varies according to the watchfulness of the garbage collectors and, of course, of the housewives.

So far, the plant operators have supplied two social clubs with spoons. Barton commented further, "We never admit finding any sterling silverware when folks are careless, or have a careless maid. We feel it is their loss and the gain of Camp Fire Cabin, the current recipient of our finds."

Editorials

RESEARCH RETURNS FROM THE WAR

The ever-growing backlog of sewage works construction projects, presaging the greatest period of growth that the field has as yet known, has overshadowed recent developments in another realm of interest that is of equal professional importance—fundamental research. Immediately upon the ending of the war there began a quiet but determined movement toward the reopening of sewage research laboratories and studies that had been suspended or curtailed by the emergency. The restaffing and re-equipping of the institutions previously engaged in sewage research has been accompanied by the establishment of several new laboratories and testing stations, with the result that many fine opportunities have been created for those who are trained and fitted for research work.

It is greatly to the credit of the technicians of this field that they admit freely the absence of satisfactory and adequate explanations for many of the things that take place in the course of sewage treatment. Domestic sewage is a heterogeneous and complex mixture, often further complicated by the addition of other complex organic industrial wastes. We are as yet able to understand only generally and vaguely the processes of biochemical reduction and oxidation that we employ to secure acceptable end products for return to Nature. Technical progress comes only as rapidly as these fundamental questions are answered, and we may expect the concerted research effort of the next few years to make up, in part at least, some of the ground lost during World War II.

The war, incidentally, spotlighted the research worker and his accomplishments so spectacularly that unprecedented impetus has been given governmental sponsorship and encouragement of research services. This highly desirable development will result in diversion of the effort that produced such amazing weapons of war and destruction into channels that will yield no less amazing instruments of peace and better living. Here is indeed a commendable governmental function, free of "pork-barrel" aspects.

The National Institute of Health is a typical example of governmental sponsorship of constructive research. Furnished with an appropriation that is insignificant in the Federal budget, this agency is extending financial aid toward the conduct of research in all phases of public health. These grants are extended without entangling habiliments of red tape, so that the grantee is allowed full freedom of action in making studies and in the dissemination of results. About 25 "Study Sections," comprised of acknowledged leaders in their respective fields serving in the capacity of consultants, process all applications for funds and assure use of the money in investigations that are likely to be most productive.

Sewage works interests are served in the NIH program through the Sanitation Study Section, which reviews all projects dealing with water supply, sewage disposal and all other elements of environmental significance. More than 40 applications have already been referred to this section, but relatively few of them pertain to sewage studies.

The Federation, through its Committee on Standard Methods of Sewage and Industrial Waste Analyses, has

made application for funds with which to make a comprehensive study of the limits of accuracy of all of the analytical methods now in use, as a basis for further development of new and improved methods. This is certainly an example of fundamental research, for the competency of all field and laboratory studies is completely dependent upon the nature and accuracy of the criteria by which results are measured. Practically all development work on "standard" methods to date has come about only through voluntary contributions of time and facilities; if the grant sought by the Federation is received it will advance our laboratory procedures by many years. The results of this work will be of value to pollution investigators, operators and industrial interests as well as to research workers.

In his fairly broad contact with the field, the writer has noted the existence of two extremist groups, both small but nevertheless vehement in their opinions. One of these groups has little time for any research that is conducted by means of bottle experiments, holding that such results are impossible of duplication on a plant scale and therefore are only of academic value. At the other extreme there are a few who incline to scoff at research that is conducted in operating plants unless it is performed by someone who counts a Ph.D. among his scholastic accomplishments. These rather narrow concepts have been manifested in occasional comments concerning the allocation of JOURNAL space to both types of papers.

The record will show that *all* kinds of research are to be encouraged to the limit. A review of the history of every important technical development in sewage treatment will reveal that bottle experiments have been responsible for many "practical" findings, and that much of the theory in current acceptance is founded upon proofs supplied by plant scale data and observations. Moreover, there have been numerous instances wherein operating puzzles have been explained by so-called "pure" research. Each of these approaches complements the other and both are important, which facts fortunately are appreciated by the overwhelming majority.

The signs are good. The prospects for construction of new pollution abatement works are better than ever before. In addition, it is evident that intensified scientific activity will preclude stagnation of practice by revealing new and better methods of designing and operating these facilities.

W. H. W.

Proceedings of Member Associations

NEW ENGLAND SEWAGE WORKS ASSOCIATION

1946 Spring Meeting

Greenwich, Connecticut, May 17, 1946

The Spring Meeting of the New England Sewage Works Association was held at the Pickwick Arms Hotel in Greenwich on Friday, May 17, 1946. The total members and guests in attendance was 140. President George H. Cramer presided at all sessions.

The morning session opened with the reading of the Secretary-Treasurer's reports, also reports by the Chairman of the Membership, Operators' Salaries, and Utilization of Sewage Sludge Committees. Upon completion of these reports, the remainder of the morning session was devoted to a symposium entitled "Control of Scum in Sludge Digestion." The various papers were presented by Joseph J. Gilbert, Engineer of the Link Belt Company, Paul Cerny in behalf of Harry E. Schlenz, Vice-President of the Pacific Flush-Tank Company, R. S. Rankin of The Dorr Company, and Henry F. Munroe for L. H. Chamberlain of American Well Works. Short discussions of these papers were given by Joseph Doman of Greenwich, Robert M. Donnelly of Camp Myles Standish and Ernest D. Mortenson of the Naval Depot at Davisville, Rhode Island.

Following the luncheon, the Association was welcomed to Greenwich by Wilbur M. Peck. F. S. Friel, Vice-President of the Federation of Sewage Works Associations, brought the members up to date on the current activities of the Federation and spoke most hopefully of the future.

The Association then proceeded on an inspection trip to the Grass Island plant at Greenwich and then to the Stamford disposal plant.

This was the largest meeting that the New England Sewage Works Association has had since April, 1941, and augurs well for the future.

WALTER E. MERRILL,
Secretary

LUDLOW CUP TO RECOGNIZE MEMBERSHIP ACTIVITY IN NORTH CAROLINA

W. M. (Bill) Piatt, for many years a leader in the affairs of the North Carolina Sewage Works Association and in the Federation, has recently offered to make available a trophy to be known as the "Ludlow Cup," to be awarded each year to the member of the association who secures the greatest number of new members during the year. The award is tendered as a memorial to the late Jacob Lott Ludlow, termed by Mr. Piatt as "the pioneer sanitarian of the Southeast." Among his contributions as one of leading early sanitary engineers, Col. Ludlow founded and served as the first chairman of the North Carolina Section of the American Water Works Association. The North Carolina Sewage Works Association was later organized by members of this section.

Competition for the Ludlow Cup is to be open to all members of the association, but the award will not be made

unless at least five new members have been enrolled during the one-year period established by the Federation for its membership contests. A member receiving the award three times, even though not consecutively, will be given permanent possession of the trophy.

With the Ludlow Cup as an incentive to membership activity, the North Carolina unit of the Federation may be expected to gain rapidly in strength. Credit for such growth will be owing to Mr. Piatt for the sincere interest which prompts his sponsorship of the award.

NEW ENGLAND SEWAGE WORKS ASSOCIATION

17th Annual Meeting

Greenfield, Massachusetts, September 13, 1946

The Seventeenth Annual Meeting of the New England Sewage Works Association was held September 13, 1946, at the Hotel Weldon, Greenfield, Massachusetts, with 98 members and guests in attendance. President George H. Craemer presided.

The morning session included the following technical papers:

"The Greenfield Sewerage System and Treatment Works: Operation, Maintenance, and Costs" by Eugene L. Bond, Superintendent of Streets and Engineering, Greenfield.

"The General Principles of Primary Sewage Treatment as Illustrated by the Greenfield Treatment Plant" by Frank L. Flood, partner, Metcalf and Eddy.

On behalf of the Committee on Operators' Salaries, the Chairman, Thomas R. Camp, summarized a report * prepared by that committee. Copies of this report were distributed to the members present and the report will be fully discussed at a subsequent meeting.

Following luncheon in the main dining room of the Hotel Weldon, the motion picture, "Clean Waters," was presented by representatives of the General Electric Company. The remainder of the afternoon was devoted to an inspection of the Greenfield sewage treatment plant.

Officers elected for 1947 were:

President: Thomas R. Camp, Boston, Mass.

First Vice-President: LeRoy W. Van Kleeck, Hartford, Conn.

Second Vice-President: Walter H. Brown, Jr., Cranston, R. I.

Directors: Eugene L. Bond, Greenfield, Mass.; Joseph Doman, Greenwich, Conn.; William S. Wise, Hartford, Conn.

Secretary-Treasurer: Walter E. Merrill, Boston, Mass.

WALTER E. MERRILL,
Sec.-Treas.

* See page 259.

NEW KENTUCKY-TENNESSEE ASSOCIATION JOINS FEDERATION

At the conclusion of the 1946 Annual Meeting of the Kentucky-Tennessee Section of the American Water Works Association at Knoxville, Tenn., on October 30, 1946, forty interested persons gathered to effect the organization of the new Kentucky-Tennessee Industrial Wastes and Sewage Works Association. By virtue of action taken by the Federation Board of Control at To-

ronto, the new association automatically became the 29th Member Association of the Federation upon the adoption of the previously approved constitution and by-laws.

Officers elected for the year 1946–47 were: Chairman—F. C. Dugan of Louisville, Ky.; Vice-Chairman—Julian R. Fleming of Knoxville, Tenn.; Secretary-Treasurer—R. Paul Farrell of Nashville, Tenn. and Federation Director—James Ellis of Kingsport, Tenn.

Of the forty charter members of the association, eighteen were from Kentucky, twenty from Tennessee, one from Georgia and one from Alabama. A number of technicians interested primarily in industrial waste problems were included in the group.

Vice-President George S. Russell and Executive Secretary W. H. Wisely represented the Federation at the organization meeting, both of whom spoke briefly in regard to the aims of the international organization. It was apparent from the enthusiasm evidenced at the meeting that the new association will be an active agency in the solution of stream pollution problems in the states it represents.

SOUTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

12th Annual Meeting

Deadwood, South Dakota, September 20–21, 1946

The Twelfth Annual Meeting of the South Dakota Water and Sewage Works Conference, which was held at Deadwood, September 20 and 21, was highly successful in every respect. Ninety members and guests registered during the two-day period.

An exceptionally interesting technical program was a feature of the meeting. Papers pertaining to sewage works presented in the general sessions on September 20 were:

"Pipe Corrosion Problems" by C. F. Logan, Cast Iron Pipe Research Assn., Chicago. Mr. Logan also showed the film "Laying Cast Iron Pipe," compliments of the Cast Iron Pipe Research Assn.

"Recent Developments in Sewage Treatment" by W. W. Towne, Director of the Division of Sanitary Engineering of the State Board of Health at Pierre.

At the annual banquet W. F. Cochrane, Senior Sanitary Engineer of the U. S. Engineers Office at Omaha, Neb., presided as toastmaster. Among the highlights of the banquet, the film "Clean Waters," acclaimed throughout the country as the leading picture dealing with stream pollution abatement, was shown.

The Sewage Works Section session on September 21, at which W. W. Towne presided, included the following papers:

"The Effect of Overload on Imhoff Tanks" by G. J. Gunderson, Superintendent of the Huron sewage treatment plant.

"Huron Sewage Treatment Development" by Alfred Ross, Superintendent of the Rapid City sewage treatment plant.

"Trickling Filter Operation" by Charles Price, Superintendent of the Rapid City sewage treatment plant.

"Sludge Digestion Tank Repair" by P. S. Steffenson, Service Engineer at Aberdeen.

"South Dakota Industrial Waste Problems" by Roy G. Spieker, Sanitary Engineer of the State Board of Health at Pierre.

The technical session was concluded with a round table discussion entitled "Sewer Maintenance and Plant Operation."

At the annual business meeting the following officers were elected to serve during 1946–47:

President: Ralph Reed, Watertown.

Vice-President: Richard Curtis, Deadwood.

Secretary-Treasurer: W. W. Towne, Pierre.

FSWA Director: Roy G. Spieker, Pierre.

W. W. TOWNE,
Secretary-Treasurer

ROCKY MOUNTAIN SEWAGE WORKS ASSOCIATION

10th Annual Convention

Santa Fe, New Mexico, September 11, 1946

The Tenth Annual Convention of the Rocky Mountain Sewage Works Association was held on September 11 at Santa Fe, New Mexico. In the absence of John Franks, President of the association, Vice-President N. P. Neilsen introduced Dr. W. B. McIntyre, State Health Officer of New Mexico, who welcomed the association and spoke briefly regarding the responsibilities of the sewage plant operator to his community.

The technical program opened with the paper "My Experience in Europe" by L. O. Williams, who related his observations on sanitary conditions and practices in Europe during the course of his military service. Clifford Morgan, consulting engineer, presented a paper entitled "Plants for Small Towns," in which he emphasized the need for careful selection of type of treatment, plant location and for attention to operating details of the design. Mr. Morgan also referred to the importance of the designer's understanding of operation problems, which he can best secure through direct contact with plant operators. The morning session closed with a showing of the moving picture "Clean Waters," which was made available through the courtesy of the General Electric Company.

The business meeting was devoted to such matters as reports of officers and committees and the election of officers. The following officers were elected to serve during the year 1946–1947: President, N. P. Neilsen; Vice-President, H. G. Watson; Secretary-Treasurer, Carroll H. Coberly. W. V. Leonard of Cheyenne continues to serve the association as its Director on the Board of Control of the Federation of Sewage Works Association until October, 1948.

The afternoon session was opened with an address on the subject "Tests for Small Plants," by Carroll H. Coberly. The value of laboratory work and the importance of proper sampling methods and laboratory technique were stressed in this talk. The topic "Operating Reports" was discussed in interesting fashion by Dana E. Kepner, who listed the reasons for maintaining complete records and gave examples of ways in which such records could be used to advantage.

The day's technical program was concluded with a round-table discussion on plant operation. Problems of grease handling and disposal, screenings disposal and filter fly control brought forth general participation in the forum and yielded several practical operation procedures.

An inspection trip of the Santa Fe sewage treatment plant brought the meeting to a successful close.

CARROLL H. COBERLEY,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
New Jersey Sewage Works Assn.	Stacy-Trent Hotel, Trenton, N. J.	Mar. 19–21
Arizona Sewage Works Assn.	Gadsen Hotel, Douglas, Ariz.	Apr. 10–12
Arkansas Water and Sewage Conf.	Engineering Auditorium, Fayetteville, Ark.	Apr. 14–16
Montana Sewage Works Assn.	Harve, Montana	Apr. 23–24
Michigan Sewage Works Assn.	Otsego Hotel, Jackson, Michigan	May 14–16
Pacific Northwest Sewage Works Assn.	Empress Hotel, Victoria, British Columbia, Canada	May 14
New England Sewage Works Assn. } Joint New York State Sewage Works Assn. } Meeting	Hotel Ten Eyck, Albany, N. Y.	May 26–27
Florida Sewage Works Assn.	University of Florida, Gainesville, Fla.	June 9–14
Federation of Sewage Works Assns.	**San Francisco, Calif.**	**July 21–24**
California Sewage Works Assn.	San Francisco, Calif.	July 21–24
Pennsylvania Sewage Works Assn.	Electrical Engineering Bldg., State College, Pa.	August
Georgia Sewage Works Assn.	Ga. Institute of Technology, Atlanta, Ga.	Sept. 17–19
Kentucky-Tennessee Industrial Wastes & Sewage Works Assn.	Brown Hotel, Louisville, Ky.	Sept. 22–24
North Dakota Water and Sewage Works Conf.	Dacatoh Hotel, Grand Forks, N. D.	September
Ohio Conference on Sewage Treatment	Deshler-Wallick Hotel, Columbus, Ohio	Oct. 2–3
Canadian Institute on Sewage and Sanitation	General Brock Hotel, Niagara Falls, Ont., Canada	Oct. 6–8
Iowa Sewage Works Assn.	Cedar Rapids, Iowa	Oct. 9–10
Missouri Water and Sewage Conf.	Jefferson City, Mo.	October
North Carolina Sewage Works Assn.	Sedgefield Inn, Greensboro, N. C.	Nov. 10–12

Twentieth Annual Meeting

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

San Francisco—July 21–24

in conjunction with

CALIFORNIA SEWAGE WORKS ASSOCIATION

Reviews and Abstracts

Edited by

H. Gladys Swope *

Allegheny County Sanitary Authority,
4501 Center Avenue, Pittsburgh 13, Pa.

The Biological Detection of Pollution. By R. W. Butcher. Presented at a meeting of the Midland Branch, The Institute of Sewage Purification, † Birmingham, October 15, 1946, 8 pp.

In 1928 the author indicated that further study should make it possible to use plants and animals as direct indicators of water pollution and make it unnecessary to rely entirely on indirect chemical analyses.

Experience has indicated that the distribution of plants and animals are correlated with the self-purification of streams mildly polluted by organic wastes as follows:

(a) On entry of the effluent the normal fauna is replaced by Tubificids and red Chironomids, the normal algal flora is much reduced, and the dominant plants are "Sewage Fungus" of which *Spaerotilus natans* is most common. Pollution is accompanied by a black silt deposit, low dissolved oxygen content, and high ammonia content.

(b) The first stage of recovery is indicated by an increase in number of Tubificids and red Chironomids, followed by small increases in the number of algae.

(c) A second definite stage is characterized by an abundant growth of water-log-louse (*Asellus*) and algae, and a sparse growth of Tubificids, red Chironomids and sewage fungus.

(d) In the next stage the water-log-louse is present in smaller numbers, there are often large numbers of snails and large populations of algae.

(e) In the "repurified" state the stream contains an abundant and varied fauna, including caddis, ephemerids and at times shrimp (*Gammarus*) and an abundant and healthy growth of weeds and algae. The chemical stages of repurification are indicated by a gradual increase in dissolved oxygen content, an oxidation of ammonia salts to nitrates and nitrites, and a decrease in B.O.D.

Recent investigations indicate that the usual chemical tests may be very misleading when used in reference to combined domestic and industrial pollution problems.

Four different conditions of pollution are referred to by the author, and tabulations of chemical, founal and microfloral data are presented for different stations along four different streams under study. The four different pollution conditions are as follows: (1) The zone of *foul pollution,* where only a few tubificids, sewage fungus and such organisms can subsist; (2) The zone of *pollution,* where the above are abundant; (3) The zone of *mild pollution,* where varied organisms like water-log-louse can subsist and the water is moderately clear; and (4) The *repurified* zone. The streams under study were The Upper Trent, The River Churnet, The River Tame, and The Middle Trent.

The chemical analyses reported include per cent dissolved oxygen saturation, ammonia nitrogen and oxygen absorbed in four hours for all rivers, tar acids and cyanides for The Upper Trent, and copper for The River Churnet. The fauna reported inclue Tubificids, Chronomids

* It will be appreciated if Miss Swope is furnished all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations and educational institutions are particularly desired.

† A Preprint.

(red), *Asellus*, Leeches, Molluses, *Gammarus*, Caddis and Ephemerids. The microflora included sewage fungus, *Stigeoclonium*, *Nitzchip palea*, *Gomphonema parvulum*, *Chamaesiphon* spp., *Cocconeis*, *Chlorococcum*, and *Achnanthesa affinis*.

The algae *Cocconeis* and *Chamaesiphon* are almost always found in normal unpolluted streams in which fish are abundant. They are indicative of the repurified zone. The diatoms *Nitzchia palea* and *Gomphonema parvulum* appear to be dominant always in the mild pollution zone.

The Upper Trent receives semi-decomposed sewage, tar acids, cyanides and clay in suspension from pottery towns. The chemical, faunal and algal characteristics of the stream are typical, except that the green alga *Stigoeclonium tenue* suddenly appeared in large numbers following the zone of foul pollution.

The River Churnet receives effluent from a sewage works, a dye works, and a copper works. Although the sewage works effluent produced only slight evidence of pollution and there was little difference in the chemical data on addition of the dye plant wastes, the biological data indicated gross pollution. Interference with fishing, although the chemical data indicated satisfactory conditions, was found to be due to one to two p.p.m. copper, which caused a decrease in algal population and an extermination of the faunal population for over ten miles.

The grossly polluted Tame developed a *Stigeoclonium tenue* zone at the downstream margin of the foulest part of the river similar to the Upper Trent. In this river the ammonical nitrogen and algal contents indicated gross pollution. However, the dissolved oxygen data indicated only moderate pollution. The sudden disappearance of tubificids at one location could be traced to a works effluent probably containing copper.

The confluence of the River Tame with the Middle Trent produced but small chemical change in the Trent. However, the *Stigeoclonium*, *Chamaesiphon*, and *Cocconeis* populations decreased appreciably.

These studies have brought attention to the fact that pollution by toxic ions may be responsible for erroneous evaluations of pollution by dissolved oxygen and B.O.D. determination methods. Biological surveys, along with chemical surveys, will give a more accurate picture of the nature and effects of pollution.

ROY F. WESTON

Report, Rivers Department, City of Manchester. 2 years ending March 31, 1944.

In 1944 the Rivers Department treated the sewage of about 775,000 people. No main drainage works were built in 1942–1944.

The Davyhulme Works are still in service, handling from 52.3 to 58.1 (Imp.) m.g.d. from 725,000 population, in various types of apparatus, including two experimental activated sludge units and seven larger units. The activated sludge treatment averaged in Imp. m.g.d. for 1942–1943 and 1943–1944, respectively, bio-aeration, 0.66; 0.59: Simplex, 1.358; 1.271: diffused air, 25.43; 22.43. The bulk of the sewage is treated at Davyhulme. However, the sewage from 47,000 population is treated at Withington. Experimental work on dewatering sludge was continued in the laboratory.

The analytical data for the Davyhulme plant show:

	1942–1943	1943–1944
Population Treated	728,000	725,000
Gal. (Imp.) per cap. per day	80	72
Raw Sewage (p.p.m.)		
Chlorine	255	234
B.O.D.	197	168
Susp. Solids (Total)	214	199
Sedimentation Effluent (p.p.m.)		
B.O.D.	120	105
Susp. Solids (Total)	76	71
Sedimentation plus Contact Beds (p.p.m.)		
B.O.D.	33 and 53	37 and 48
Susp. Solids (Total)	32 and 37	36 and 35

Activated Sludge Data:

	1942-1943					1942-1943				
	Bio-Aeration	Simplex	Diffused Air			Bio-Aeration	Simplex	Diffused Air		
			1	2	3-7			1	2	3-7
Detention (hr.)	16.7	11.8	9.2	9.6	9.0	18.7	12.6	9.4	9.3	10.8
B.O.D. p.p.m.	12.2	12.7	14.6	9.4	11.6	10.1	10.3	19.4	9.1	18.9
Susp. Solids, p.p.m.	18	19	20	18	19	15	16	23	17	25

Sludge disposal was as follows:

Type of Sludge	Tons		Dry Solids, Tons	
	1942-1943	1943-1944	1942-1943	1943-1944
Detritus	37,845	35,410	—	—
Settled Sludge	245,460	190,200	22,337	17,594
Digested	23,580	16,560	1,980	1,598
Activated (densified)	207,140	264,990	3,330	3,797

Detritus is dumped and covered with soil. Settled and digested sludge is chiefly sent to sea.

Excess activated sludge totaled, respectively, tons:

	Wet	Dry
1942-1943	1,267,660	7,950
1943-1944	1,431,800	6,590

About one-third is pumped to the inlet of the sedimentation tanks. The remainder is densified with a picket fence thickener, then settled and largely broadcast on land and ploughed in when dry. About 10 per cent of the solids are digested in heated tanks. A small remainder is digested in lagoons, used in emergencies.

Tests were made of the manurial value of various sludges, on plots treated with phosphate and potash. In growing potatoes, digested sludge showed no advantage, but activated sludge showed about 22 per cent greater yield than where no sludge was used. In growing swedes, activated sludge showed an additional yield of 52 per cent; whereas digested sludge showed only 6 per cent increase.

The Withington Works treated 2.24 (Imp.) m.g.d. and 1.866 (Imp.) m.g.d. respectively, in 1942–1943 and 1943–1944. The sewage is weaker than at Davyhulme (p.p.m.).

	1942-1943	1943-1944
B.O.D.	149	131
Suspended Solids (Total)	71	74

The activated sludge plant operated as follows:

	1942-1943		1943-1944	
	1	2	1	2
Volume (Imp.) Gal. p.d.	265,200	1,217,200	204,300	900,800
Detention Period, hr.	5.6	5.1	7.3	6.9
Air (cu. ft. per Imp. Gal.)	1.4	0.85	1.7	1.1
Effluent, p.p.m.	—	—	—	—
B.O.D.	9.8		8.5	
Susp. Solids	10		10	

The sludge is partly used by farmers, after lagooning, or pumped to sludge trenches.

The report contains four Appendices:

I. Report of the General Manager (J. M. Wishart).
II. Cost Statistics.
III. Treatment of Settled Sewage by the Activated Sludge Process in Aeration Channels of Different Lengths (J. M. Wishart, C. Jepson, A. Bradwell).
IV. Dewatering of Sewage Sludge by Coagulation and Vacuum Filtration. Part I. Laboratory Experiments * (J. M. Wishart, C. Jepson, L. Klein).

III. The Davyhulme Works has an activated sludge plant with 7 units. Six units consist each of one aeration tank and 16 settling tanks. One unit consists of an aeration tank only, which reactivates the sludge returned to units 4 to 7. Each aeration tank is 354 ft. long by 45 ft. wide, 15 ft. effective depth, divided into three channels connected in series. The total length of travel is 1,062 ft. in each unit. There are three longitudinal lines of diffusers in each channel, with a transverse line every 42 ft., in front of a baffle wall, under which the mixed liquor flows. In units 1 and 2, the return sludge is not reactivated. These independent units have been in service since 1935. The principal results cited are for units 1 and 2, with aeration periods ranging from 6.8 to 9.4 hours. The conclusions reached were that no advantage was gained by very long aeration channels. No disadvantage was found in 342 ft. channels, which probably avoid short-circuiting. Curiously, the amount of air used is not stated. Effluents contained from 8.7 to 12.9 p.p.m. B.O.D.

LANGDON PEARSE

Annual Report of the City Engineer, Johannesburg, South Africa, for Year Ending June 30, 1945. BY E. J. HAMLIN. 60 pp.

This report covers the operation of six sewage treatment works. At two, sewage farming is practiced. The crops are varied, including rye grass, lucerne, and vegetables. Six crops of lucerne were produced in one year. Public grazing is also a source of revenue. The total revenue from the two farms was 20,600 pounds, of which grazing contributed 12,668 pounds.

At the other four works, no changes were made, except at Delta, where a new trickling filter was added. The flow at the four works increased 20 per cent.

The report also reprints articles by —

B. H. Wilson,* Some Risks of Transmission of Disease during the Treatment, Disposal, and Utilization of Sewage Effluent and Sewage Sludge (26 pp.).
E. S. Hogg, The Washing of Watercress Grown in Sewage Effluent (2 pp.).
H. Wilson, The Use of Sludge Digester Gas in the Syntheses of Organic Chemicals (2 pp.). This article relates to the conversion of digester gases to methyl alcohol and its dehydrogenation to formaldehyde in a pilot plant.
H. Wilson, Recovery and Purification of Sewage Grease at Johannesburg (2 pp.).

The crude grease was very objectionable. However, treatment in a pilot plant with sulfuric acid, washing, heating with a Twitchell reagent to split the fat, washing with hot water, neutralization with ground limestone, distillation, and cooling produced a grease which could be pressed and redistilled to a high quality grease. The process apparently may produce some profit.

Daily 1,200 to 1,400 lb. of crude wet grease yielded 400 to 500 lb. of mixed distilled fatty acids, and this yielded 150 lb. of liquid or oleic acid and 300 lb. of solid or stearic acid, plus some 50 to 100 lb. of still residue grease. "Sentimental objection to the origin will, of course, limit the use of highly purified products," such as shaving, soap, creams, and cosmetics!

LANGDON PEARSE

Prevention of Pollution in the Tame Basin. BY H. CLAY. *Institute of Sewage Purification.* 8 pp. preprint. Nov. 21, 1946.

This is a history of the control of pollution in the Tame River basin in England

* EDITOR'S NOTE: This was abstracted in SEWAGE WORKS JOURNAL, 765 (July, 1946).

* Abstracted in SEWAGE WORKS JOURNAL, 17: 650, 1297 (May and Nov., 1945).

covering a period of over 100 years. Since its formation in 1877 the Birmingham, Tame and Rea District Drainage Board has been a major factor in the removal of pollution. However, areas outside the District served by that Board are seriously polluting the River Tame above its entrance into Birmingham. Much of the difficulty is from industrial wastes, containing spent acids, oil, gas wastes, and cyanides. The effect of metallic salts present in the river require further observation. The conditions were greatly aggravated during the war.

LANGDON PEARSE

East Bay Municipal Utility District. Report on Sewage Disposal for Special District No. 1. BY S. A. GREELEY, C. C. KENNEDY AND N. T. VEATCH. 36 pp. July 1, 1946.

This report covers the pollution of San Francisco Bay, Oakland Outer Harbor, the Estuary, San Leandro Bay, and certain offshore water north of the Bay by Alameda, Albany, Berkeley, Emeryville, Oakland, and Piedmont, all on the easterly shore of San Francisco Bay. These tidal waters receive a flow from the San Joaquin and Sacramento Rivers. The California State Board of Health has declined to permit the discharge of raw sewage therein.

The sewered area in the District is 35,569 acres, out of a total land area of 54,643 acres. From May to October the average monthly rainfall ranges from 0.01 to 0.93 inches. The monthly humidity ranges from 60 to 89 per cent. The present (1944) water supply is 51 m.g.d. or 88.9 g.c.d., of which 35.9 m.g.d. or 62.7 g.c.d. is domestic use. The industrial sewage is somewhat higher than the water supplied. The water supply contains 15.9 p.p.m. as sulfate (SO_4). The 1940 census population was 447,846; the estimated population in 1944 being 573,709. The population per acre of sewered area in 1944 was 16.1. 32 sewers discharge into the Bay, of which 16 are sanitary sewers only. The separation of the rain water is advised on the other 16 sewers. The industries are varied. For the purpose of the report, the data resewage flow are as follows: domestic, 52 g.c.d.; industrial, 47 g.c.d. (1,944), 53.5 g.c.d. (2,000); infiltration, 94 g.c.d. (1,573 g.a.d.) in 1,970 and 78.1 g.c.d. (1,484 g.a.d.) in 2,000. The maximum rate of rainfall provided for in the sewage disposal projects is 0.04 in. per hr. and a sewage runoff of 0.02 in. per hr. (or 13,000 g.a.d.). The maximum suspended solids were estimated at 0.224 lb. per cap. p. d., and the 5-day B.O.D. at 0.246 lb. per cap. p. d. For an annual plant loading, suspended solids were computed at 0.17 lb. per cap. p. d. The intercepting sewers were computed as of the year 2,000.

The minimum requirement for treatment is to prevent stranding of visible sewage solids along shore and formation of sludge deposits in shallow water.

In San Leandro Bay and certain other waters, complete treatment in indicated. In San Francisco Bay, where deep waters and a strong current exist, sedimentation with effluent screens and chlorination should suffice. The installation of flocculation tanks can be postponed. Four projects were reviewed, costing from $21,384,000 to $22,935,000, with an operating cost ranging from $503,100 to $590,800. The dewatering of digested sludge by vacuum filters, and drying the cake with heat, is recommended, in the hope it can be sold as fertilizer. The estimated cost of the sewage treatment works is $12.00 per cap. (on 567,000 pop.) and the annual cost $2.21 per cap., including debt service. The recommended project is estimated at $22,456,000, with a single sewage treatment plant at 34th St. in Oakland.

LANGDON PEARSE

Activated and Digested Sewage Sludge in Horticulture. BY A. HOWARD. *Institute of Sewage Purification.* 12 pp. preprint. November 20, 1946.

Howard discusses the general problem in a sketchy way from the standpoint of composting, recommending activated sludge as an activator therein. Lacking a ready and economic means for drying activated sludge, digestion of mixed activated and fresh sludge is effective. He does not like air-dried digested sludge as an activator. In making compost, calcium carbonate is also very desirable. He claims that a market exists in Great Britain and urges composting of other refuse, such as garbage. At Dartford, air-dried digested

sludge has sold at pre-war prices at 2s. 6d. (50 cents) per 100 lb.; £2 ($8.00) per ton; 8£ 15s. ($35.00) per five tons, all plus haulage. He argues that the value of air-dried sludge is from 2.5 to 3 times the commercial value of the nitrogen and phosphorus present (but offers no evidence of sales). To recover soluble salts from sewage effluents he suggests cultivating water hyacinth and its use in making compost. The Indore method of composting is described, using organic residues, animal manure (including night soil), or sewage sludge, earth and moisture, in a loose pile.

LANGDON PEARSE

Heat Treatment of Sewage Sludge. BY S. C. EVANS AND F. W. ROBERTS. *Institute of Sewage Purification.* 12 pp. preprint. November 20, 1946.

This describes a process in use at Horsham, Halifax and Luton (population 100,000), England, which heats sewage sludge to a temperature so that after cooling it may subsequently be filtered. The heating is done in a closed vessel at temperatures between 300 and 400° F. Heat is recovered by a heat exchanger, which pre-heats the incoming sludge. Heat is then applied by steam jets. Preferably grit and screenings should be removed first. The sludge should pass through a ⅜-in. mesh. Storage tanks serve as concentrators.

Experimental work between 1934 and 1940 showed that all sludges responded to such treatment. From 15–30 min. of heat are required.

The heat exchanger consists of a 3-in. pipe inside a 4½-in. pipe. Cold sludge enters the annular space, the heat-treated sludge passing out through the inner tube. The sludge is pumped through and into the heating vessel against steam pressure with pump pressures from 350 to 450 lb. per sq. in. (sic!). The outer tube is enclosed in a logged casing, through which the vented gases from the boiler furnace pass.

After treatment, the sludge settles quickly, to a thick sludge (12 per cent solids) of about 50 per cent of the original volume. Such sludge filters readily in a press, when fed at 100 lb. per sq. in.

The press cake has a moisture content around 40 to 50 per cent and may be dried further on a furnace grate, or air-dried under an open shed, or dried in ovens. The dry matter has a B.T.U. content of 12,000.

The dried sludge burns readily if the moisture is not over 30 per cent.

LANGDON PEARSE

Bradford Corporation's Esholt Sewage Works. *The Surveyor,* 105, 769–771 (Oct. 4, 1946).

The population served is 262,500. The average d.w.f. is 18.0 m.g.d. About one-half the d.w.f. is domestic sewage and the balance trade effluents derived predominantly from wool-scouring plants and dye works. There is some waste from breweries and chemical works.

The strength of the sewage based on a twelve months' period is as follows:

	P.P.M.
Oxygen absorbed (4 hours at 80° F.)	246
Alkalinity to methyl orange	815
N as free ammonia	44
N as albuminoid ammonia	29
Suspended solids	1,450
Grease	890

During the daily hours of peak flow the above figures for average strength may be more than doubled. The emulsified state of the grease renders treatment difficult.

Sewage after passing through screens and detritors is treated with sulfuric acid to 100 p.p.m. acid reaction which "cracks" the emulsified suds and the sludge containing the bulk of the grease settles out. The tank effluent is passed through trickling filters, humus tanks, and a clarification lake before discharge to the river Aire.

The outfall sewers discharge into a pit 11 ft. in diameter where coarse sand and rags are deposited. About 7,300 tons are dredged from the pit annually.

Coarse screens are used to take out large floating objects. The mechanically cleaned screens with 1¼ in. openings are not used as it has been found that sludge pressing is facilitated by the presence of wool fibers, cotton waste, and paper.

There are two detritus tanks, each 150 ft. long, 40 ft. wide, and 1½ ft. average depth. The sludge is withdrawn by gravity once each week.

There are seven storm water tanks having a total capacity of 11 million gallons.

An inverted siphon conveys sewage

from the storm water tanks to the precipitation tanks. The siphon is 2,250 ft. long and has a drop of 80 ft. The siphon comprises 3 cast iron pipes 4 ft. in diameter. At the maximum rate of flow the head loss is 4½ feet. The siphons are kept clean by the passage once a week of a wooden ball 3 ft. 9 in. in diameter through them.

The siphons discharge into a mixing tank where sulfuric acid is mixed with the sewage. The tank has a capacity of 445,000 gal. and provides 40 min. mixing at normal d.w.f.

About 12,000 tons of acid are used annually, of which amount 9,000 tons are manufactured in the department's chemical works at Frizinghall.

The precipitation tanks are approached by an inlet channel 22 ft. wide by 5 ft. deep. The primary tanks are 20 in number, each 140 ft. long, 60 ft. wide, and 7 ft. 4 in. average depth. The secondary tanks, of which there are 20, are 140 ft. by 65 ft. by 10 ft. 2 inches. The capacity of the primary tanks is 7½ million gallons; the capacity of the secondary tanks is 11½ million gallons. Thus the tank capacity is more than the normal d.w.f.

Most of the sludge is precipitated in the primary tanks. The average daily volume of wet sludge is 700 tons. The primary tanks are run until they are full of sludge to increase the sludge density. Between the primary and secondary tanks sewage from Baildon, Guiseley and Yeadon is added. This has an alkaline reaction sufficient to raise the pH of the sewage going to the filters to 6.0.

There are 53½ acres of filter beds, 6 ft. deep. The filter media are hard Yorkshire coal, sized ¾ in. to 1¼ inch. Sewage is applied to the filters with Hartley's rectangular distributors. The average dry weather loading is 35 g.c.y.d. Fine screens are provided ahead of the filters to take out fungus which develops in the conduit leading to the filters due to the acid condition of the sewage.

There are four humus tanks, each 450 ft. long by 5 ft. deep, having a combined capacity of 4,500,000 gal. and covering an area of 3 acres. Three tanks are normally in operation, the fourth being desludged. Sludge is returned to the precipitation tanks.

The clarification lake covers 14½ acres and contains 10,500,000 gallons. It receives the effluent from the humus tanks.

Sludge from the detritus tanks, storm water tanks, and precipitation tanks gravitate to a collection well. The mixed sludge has a moisture content of 80–85 per cent. The sludge is screened and then boiled with steam and sulfuric acid. Eight 7-ton capacity steel vats lined with blue brick are used for heating the sludge. Gases from the vats are exhausted through a stainless steel duct to a fume tower containing a spray of chlorinated water for deodorizing them.

The conditioned sludge is pressed in 128 sludge presses. Each press contains 46 plates 36 in. square and having a capacity of 32 cwt. of press cake containing 26 per cent moisture. The pressing operation, assisted by the admission of superheated steam, takes 48 hours. The daily production of sludge cake is about 75 tons.

Hot liquor from the presses is conveyed to tanks where the water and grease are separated. The water is returned to the incoming sewage.

The sludge press cake is air dried for 6 to 12 months and then ground to a fine powder containing about 20 per cent moisture. It is readily sold.

The boiler house is adapted for using sludge cake or grease as fuels.

The grease is treated in 30 lead lined steel vats, each of 7 ton's capacity. Each vat is fitted with steam, acid, and water supply lines. The grease is clarified by boiling with sulfuric acid. The clarified grease can be drained to drums or pumped into rail or wood tank wagons or into grease storage tanks. The weekly output is about 130 tons. The waste liquor, which is highly corrosive, is collected in a sump and pumped into a lead-lined tank wagon. The tank wagon is drawn by locomotive to the mixing tanks where it is mixed with the incoming sewage.

Recovered grease has been sold since 1902. In 1935 a special research drive was begun to discover fresh uses for the grease. Old grease stocks have disappeared and new specialized products have been marketed successfully. Among them are: Recovered wool grease in three qualities:

Quality A. This is the crude grease as recovered and forms the largest item in the department's sales. It is sold chiefly to

wool grease distillers, who produce from it stearine, oleine, and pitch.

Quality B. A deodorized form of crude grease, used in the manufacture of lubricants, leather dressings, etc.

Quality C. This grease is bleached and deodorised and is used for making special lubricants and dressing compounds.

Neutralized Wool Grease. Made in three qualities—hard, medium, and soft—this grease has been widely used for purposes of rust prevention.

Crujol. A crude soda soap derived from wool grease. It is an excellent emulsifying agent and is, together with "A" grease, supplied to all the British railway companies, who use it exclusively for the manufacture of their wagon axle grease. Crujol is also used in the preparation of water paints.

Scrojol. A dry powdered soap, useful for certain washing and scouring purposes.

Lanalose. A very useful oil paint component, used either with or as a substitute for linseed oil. The exterior of Esholt Hall has been painted with this type of paint and it is also used on the corporation's housing estates.

Varwolax. An unsaponifiable drying oil which, used in conjunction with Crujol, forms a very successful washable water paint. The interior of Esholt Hall is decorated with this material.

Lanaloid. A synthetic wool wax used as a constituent of paints and polishes.

During the last 40 years the Department has sold over 2,750,000 pounds worth of grease. The income from sales last year covered all salaries and wages, repairs and maintenance, chemicals, fuel, etc., and also part of the interest and sinking fund charges, the sewage rate being required solely to meet the remainder of the latter charges.

K. V. HILL

Experiments at Leicester on the Filtration of Sedimented Sewage Diluted Bacteria Bed Effluent. BY S. J. ROBERTS. *The Surveyor,* **105**, 741–746 (Sept. 27, 1946).

The Valley Works at Leicester include thirty 100 ft. diameter filters, six ft. deep. The filter media are broken granite, the bottom 1 ft. of depth of stone being sized at 2¼ in. and the top five ft. sized between 1½ to 2 inches. The filters were designed to treat sewage at the rate of 70 gal. per cu. yd. per day.

Plans were projected in 1939 for increasing the capacity of the plant with a bioflocculation unit and five new bacteria beds; but construction of the proposed units was not carried out. Instead, experiments have been carried on to ascertain the performance of the filters under increased loadings of settled sewage and humus tank effluent.

During the course of the experiments one filter was used as a control and dosed at the design rate of 70 gal. per cu. yd. per day; another filter unit was dosed at varying rates as follows:

Period	Gallons per Cubic Yard per Day		
	Settled Sewage	Humus Effluent	Total
Mar. 13–27, 1942.....	70	70	140
Mar. 28–Apr. 22, 1942....	90	90	180
*Apr, 23–Sept. 29, 1942....	126	60	180
Oct. 27, 1942–Dec. 31, 1943	175	175	350
**Jan. 1, 1944–Dec. 31, 1945.	—	—	350

* Filter rested Aug. 17–28 for alterations in feed channel; also from Sept. 29–Oct. 27 for installation of larger arms on distributor.

**8:00 A.M. to 11:00 A.M.....	175	175	350
11:00 A.M. to 7:00 P.M.....	250	100	350
7:00 P.M. to 10:00 P.M.....	175	175	350
10:00 P.M. to 8:00 A.M.....	100	250	350

After October 27, 1942, the distributor on the experimental filter (4 arms) working at 350 g.c.y.d. rotated once every 54 sec., applying an average surface dose of 0.11 gal. per sq. yd. each 13.5 seconds.

On the control filter the distributor rotated once every 160 seconds. With 25 per cent of the bed surface wetted by each arm, the average dose was 0.26 gal. per sq. yd. every 160 seconds.

Measurements of time of retention of the sewage in each bed were made in May, 1944. In the control unit the sewage was retained 75 min.; in the experimental unit the retention time was 37 minutes.

Analytical data on the characteristics

of the sewage and sewage mixtures applied to the control and experimental filters and the effluents of the two filters are presented in the paper. These are averaged and summarized as follows:

Period: Oct. 27, 1942–Dec. 31, 1943

Applied Sewage	Control Filter	Experimental Filter
Albuminoid and ammonia N	—	—
Nitrite and nitrate N	0	9.0
5-day B.O.D.	172	96
Suspended solids	79	56
Filter Effluent		
Albuminoid and ammonia N	—	—
Nitrite and nitrate N	21.2	15.1
5-day B.O.D.	41	37.5
Suspended solids	64	55

Period: Jan. 1, 1944–Dec. 31, 1944

Applied Sewage	Control Filter	Experimental Filter
Albuminoid and ammonia N	45	40.1
Nitrite and nitrate N	—	5.4
5-day B.O.D.	167	102
Suspended solids	60	51
Filter Effluent		
Albuminoid and ammonia N	24.2	27.3
Nitrite and nitrate N	21.0	13.7
5-day B.O.D.	42.0	32.2
Suspended solids	75.0	55

Period: Jan. 1, 1945–Dec. 31, 1945

Applied Sewage		
Albuminoid and ammonia N	42.7	38.2
Filter Effluent		
Albuminoid and ammonia N	25.3	24.8

(NOTE: All results in parts per million)

Analyses of the sewage applied to the experimental filter and the effluent were made on March 1–2, 1945, to determine the variation in strength due to variation in quantities of settled sewage and filter effluent which were applied to the filter. These are shown below:

Time	Applied Sewage			Filter Effluent		
	Alb. NH_3	NO_2 NO_3	S.S.	Alb. NH_3	NO_2 NO_3	S.S.
7:00 A.M.–10:00 A.M.	46.8	9.4	48	40.3	10.4	108
11:00 A.M.–7:00 P.M.	55.2	1.15	60	45.8	7.8	72
8:00 P.M.–10:00P.M.	46.0	8.8	50	42.3	10.5	95
11:00 P.M.–6:00 A.M.	42.7	17.0	42	38.4	13.3	124

The filter can cope with varying loads during the day and recover during the night.

Experiments were conducted to determine the effect of dilution with effluent and presence of nitrite and nitrate upon the biological surface growths. Four filters were made from 6-in. by 1-in. glass tubes and filled with short lengths of ¼-in. glass tubing. These were dried and weighed before dosing them (at 350 gal. per sq. yd. per day) with

A. Settled sewage.
B. Settled sewage plus bacteria bed effluent.
C. Settled sewage plus calcium nitrate solution (2.5 parts per 100,000 nitric nitrogen).
D. Settled sewage plus calcium nitrite solution (0.25 part per 100,000 nitrous nitrogen).

B, C, and D received an equal volume of effluent, nitrate solution and nitrite solution, continuously from Feb. 5 to March 15, 1945.

The filters were then drained for two days and weighed; after drying at 105° C., they were reweighed to determine the dry weight of the film as follows:

	A	B	C	D
Weight of film, gms.	20.78	12.00	18.54	17.03
Weight of dry film, gms.	0.88	0.94	0.89	0.77
Dry matter in wet film, %	4.25	7.84	4.80	4.52

The experiment was repeated in November, the only difference being that the filters stood for two hours until no further water drained away. The results were:

	A	B	C	D
Weight of wet film, gms.	12.20	13.92	13.74	11.55
Weight of dry film, gms.	0.34	0.78	0.35	0.305
Dry matter in wet film, %	2.78	5.57	2.55	2.64

Samples of the sewage and effluents tested for ammonia and oxidized nitrogen showed a slight increase of ammonia in the effluent from A with no oxidized nitrogen present; B showed a slight decrease in ammonia with almost complete loss of the nitric nitrogen and an increase in nitrous nitrogen; C gave a decrease in ammonia, a big reduction in nitric and production of nitrite; and D gave a decrease in ammonia

and no nitric or nitrous nitrogen present.

It was concluded that the weights of the wet and dry films demonstrated the densification of the biological film when the sewage applied was diluted with effluent; the effect of nitrate and nitrite is negligible.

In order to check the performance of a bed under heavier loading than 70 g.c.y.d. a test run was made of a single filter (bed 23, in comparison with the experimental filter) for the period Oct. 16, 1943 to Jan. 20, 1944, during which time the bed was dosed with 175 g.c.y.d. of settled sewage. Weekly average results for the entire period were as follows:

	Characteristics of Effluents P.P.M.	
	Experimental Filter	Filter 23
Dosage, g.c.y.d.	(1) 350	(2) 175
Alb. plus ammonia N	23.2	38.3
Nitrite plus nitrate N	12.9	5.5
Suspended solids	60.2	54.0
5-day B.O.D. (Shaken sample)	45.5	68.6
5-day B.O.D. (Filtered sample)	11.6	26.4

The surface of bed 23 developed a heavy fungal growth and began to clog. It was concluded that increased dosage (without dilution with effluent) was of no advantage.

The author concludes that the volume of sewage treated by a bed can be increased by 2.5 with dilution. At the Valley Works provision will be made to return settled filter effluent to the settled sewage just before application to the beds to insure that dissolved oxygen and nitrate will be available to the biological growths on the beds.

K. V. HILL

Mitchell Laithes and Ravensthorpe Sewage Disposal Works. By E. H. STAYNES. *The Institute of Sewage Purification.* 6 pp. preprint. June 27, 1946.

The sewage of the county borough of Dewsbury is disposed of at four works: Mitchell Laithes, Ravensthorpe, Thornhill and Smithy Brook. An important feature of Mitchell Laithes and Raventhorpe Works is the treatment of considerable amounts of textile industrial wastes in conjunction with domestic sewage. Piece and yarn scouring are predominant with quite appreciable volumes of rag washing and carbonizing waste.

The Mitchell Laithes Works serves an estimated population of 35,000 people and has an average daily dry-weather flow of 2,880,000 gallons.* Out of this total 1,440,000 gal. are domestic sewage; 240,000 gal. are infiltration; and 1,200,000 gal. are industrial waste. Storm water up to six times the dry weather flow is treated. However, storm water between three and six times the dry weather flow is only given plain sedimentation. The usual dry-weather flow passes through a detritus pit, 29½ ft. long by 11½ ft. wide by 21 ft. deep, from which it passes through ¾-in. bar screens. It is pumped to sedimentation tanks, 120 ft. long × 70 ft. wide × 7 ft. deep. The sewage then passes to bacteria beds which are filled with hard clinker. The bacteria beds have a total area of 4½ acres. The effluent from these beds passes to humus tanks before discharge to the River Calder. Raw sludge is pumped to land areas and is either plowed under, covered in ditches or lagooned.

The Ravensthorpe Sewage Works serves an estimated population of 6,000 people and has a daily dry-weather flow of 840,000 gallons. Out of this total 180,000 gal. are domestic sewage; 156,000 gal. are infiltration; and 504,000 gal. are industrial wastes. Treatment is essentially the same as at the Mitchell Laithes Works, except that rotary distributors are used on the bacteria beds instead of traveling distributors and all raw sludge goes to the Mitchell Laithes Works.

The strength of the sewage at both the Mitchell Laithes and Ravensthorpe Works is very similar in spite of the difference in amount of industrial wastes. The greater proportion of scouring liquor from the textile industry receives treatment for the recovery of grease before being discharged to the sewers. Chemical precipitation with aluminoferric and sulfuric acid has been necessary at Ravensthorpe at times of

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* *Abstractor's note:* All quantities shown are in U. S. gallons.

abnormal flow and when the sewage has been exceptionally strong in character. Good results have been obtained consistently with this treatment, as the final effluents are both usually well within Rivers Board standards.

ROBERT P. LOWE

Evaluation of Professional Objectives in the Design of Sanitary Engineering Works. Report of a Committee of the Sanitary Engineering Division. *Proc., A.S.C.E.,* **72**, 69–82 (January, 1946).

The nature and scope of this report does not permit of an adequate abstract. The purpose of the committee was: ". . . to evaluate the professional objectives of engineering in designing water purification and sewage treatment works with reference to the influences of proprietary equipment and processes upon the development of effective and economical plans that will best meet the need of the community or industry to be served."

The report is written under the following headings:

1. Origin and Purposes of Committee.
2. The Situation.
3. Scope of the Committee's Work.
4. Trends in Engineering Practice in Dealing with Patented Equipment and Processes.
5. Patents and Patent Claims.
6. Legal Requirements for Engagement of Engineering Services by Municipalities.
7. Conclusions.

T. L. HERRICK

Efficiency of Elutriation Process. BY GORDON C. LAIDLAW. *Water and Sewage,* **84**, 24 (January, 1946).

Special tests have been made from time to time in connection with the elutriation process as used at the sewage works of the Greater Winnipeg Sanitary District. A summary of results may be stated briefly as follows:

The alkalinity appears to be a good gauge of the removal of soluble compounds from the sludge liquor during elutriation. Digestion during storage of elutriated sludge does not appear to be serious over a 2 or 3 day period. Recirculation of sludge in the secondary tank does not always result in a uniform reduction of dissolved compounds, probably due to short circuiting.

There is a considerable loss of solids over the weirs with a high level of stored sludge. With the high sludge levels, however, a sludge of 7 to 8 per cent solids can be produced. This points to the possible advantage of having a third tank.

T. L. HERRICK

Elimination of Digesters. BY H. O. HALVORSON AND RANDOLPH L. SMITH. *Water and Sewage,* **84**, 20 (January, 1946).

Since 1938 seven plants have been designed and built in which digestion tanks were omitted. They were omitted for the purpose of eliminating supernatant liquor with its high B.O.D. and organic matter content which is difficult to handle, and to eliminate nitrogen from the supernatant which eventually finds its way to the effluent as ammonia, nitrites or nitrates. Other ends in view in the design included low initial cost, reduction of odors to a minimum and simplicity of operation.

Fine screens are used as the primary unit. A fourteen mesh screen has been used in most of the plants, though twelve mesh has been found satisfactory.

The trickling filters at these plants are tile media aero-filters. This tile provides one-inch diameter vertical holes separated by ¼-inch partitions. Distribution must be rain-like. Recirculation is necessary only when the flow of sewage is too low to operate the distributor.

At plants for communities up to 5,000 population, sludge from the final settling tanks is pumped to a tank equipped with a lightning mixer. Here ferric chloride and copper sulfate are added and mixed for 20 seconds. The chemically dosed sludge is discharged to drying beds from which it can be removed at about 75 per cent moisture after 4 to 6 hours. The beds must be covered and provision made for transporting dried sludge to trucks for hauling. Vacuum filters should be used in plants serving over 5,000 population.

T. L. HERRICK

Scum Accumulations in Sludge Digestion Tanks. By D. L. McLean. *Water and Sewage,* **84**, 17 (February, 1946).

The sewage treatment works of the Greater Winnipeg Sanitary District is equipped with four sludge digestion tanks. Two are provided with turbo-mixers for use as primary units and the other two, without mixers, were intended for use as secondary digesters. With increased loads on the plant under war conditions the four tanks were used as single digesters. This made it possible to make a study of the effect of the turbo-mixers on scum accumulations, as the digested sludge is drawn to elutriation tanks where scum formation can be observed, corresponding to the scum which would form on the secondary digesters without stirring apparatus. Records were also maintained regarding scum accumulations in the digesters.

It was observed that the scum weighs from 50.0 to 53.5 pounds per cubic foot. Nearly all the particles will sink if freed from gas bubbles which support them. The scum can be settled by use of the turbo-mixers or by sprays. It was found that when scum is ground to pass a No. 30 screen and held on a No. 100 sieve it will digest as well as any raw sludge.

No trouble from scum is encountered in the digesters equipped with mixers as long as temperatures are controlled and the digesters are not overloaded. Scum accumulates to a depth of 8 to 14 ft. in a year in the other units. The mixers permit an additional raw sludge loading of 20 to 25 per cent to be placed on the digesters.

T. L. Herrick

Federation of Sewage Works Associations

1946

Annual Directory

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DIRECTORY OF MEMBERS

FEDERATION OF SEWAGE WORKS ASSOCIATIONS, INC.

325 Illinois Building, Champaign, Ill.

1946–47 OFFICERS

President: Francis S. Friel

Vice-President: George S. Russell

Treasurer: W. W. DeBerard

Executive Secretary-Editor: W. H. Wisely

Advisory Editor: F. W. Mohlman

PAST PRESIDENTS

Name	*Period Served*
Charles A. Emerson	1928–41
*Arthur S. Bedell	1941–42
George J. Schroepfer	1942–43
A. M. Rawn	1943–44
Albert E. Berry	1944–45
John K. Hoskins	1945–46

HONORS AND AWARDS

Honorary Members

The qualifications for Honorary membership in the Federation are set forth in Article II, Section 4 of the By-Laws. Honorary Members are elected upon recommendation by a committee comprising the President and four latest Past Presidents, the senior Past President as chairman, in accordance with a policy adopted by the Board of Control on October 23, 1943. Honorary Members elected to date are as follows:

Charles Alvin Emerson	1941
*Arthur S. Bedell	1942
Julius W. Bugbee	1942
Langdon Pearse	1942
Charles Gilman Hyde	1943
Howard Eugene Moses	1943
Floyd William Mohlman	1944
Willem Rudolfs	1945
William John Orchard	1946

The Harrison Prescott Eddy Medal

The Harrison Prescott Eddy Medal is awarded annually to a member of any Member Association of the Federation "for outstanding research contributing in important degree to the existing knowledge of the fundamental principles or processes of sewage treatment, as comprehensively described and published during any stated year in SEWAGE WORKS JOURNAL." The award commemorates Harrison Prescott Eddy, a famous engineer and a pioneer in the art of sewage treatment.

Past recipients of the award are:

Harry Willard Gehm	1943
John Raymond Snell	1944
Lloyd R. Setter	1945
H. Heukelekian	1946

The George Bradley Gascoigne Medal

The George Bradley Gascoigne Medal is awarded annually to a member of any Member Association of the Federation "for outstanding contribution to the art of sewage treatment works operation through the successful solution of important and complicated

* Deceased.

operational problems, as comprehensively described and published during any stated year in SEWAGE WORKS JOURNAL." This award is in memory of George Bradley Gascoigne, a prominent consultant from 1922 to 1940, who demonstrated an unusual interest in matters of sewage works operation.

Past recipients of this award are:

Kerwin L. Mick	1943
James T. Lynch and Uhl T. Mann	1944
John D. McDonald	1945
LeRoy Winfield Van Kleeck	1946

The Charles Alvin Emerson Medal

The Charles Alvin Emerson Medal is awarded annually to a member of any Member Association of the Federation "for outstanding service in the sewerage and sewage treatment works field, as related particularly to the problems and activities of the Federation of Sewage Works Associations in such terms as the stimulation of membership, improving standards of operational accomplishments, fostering fundamental research, etc." This award honors Charles Alvin Emerson, who served as President of the Federation from 1928 to 1941 and holds the distinction of being its first Honorary Member.

Past recipients are:

Floyd William Mohlman	1943
Willem Rudolfs	1944
Harold Warner Streeter	1945
F. Wellington Gilcreas	1946

The Kenneth Allen Award

Each Member Association of the Federation is privileged once in each three years to designate one of its members to receive the Kenneth Allen Award "for outstanding service in the sewage works field, as related particularly to the problems and activities of any Member Association." The award commemorates Kenneth Allen, an eminent engineer who made notable contributions to the creation of the Federation and the New York State Sewage Works Association.

Recipients of this award have been:

1943

Name	*Member Association*
Harry Thornton Calvert	I. S. P. (England)
Edward F. Eldridge	Michigan
John Kurtz Hoskins	Federal
Fred Merryfield	Pacific Northwest
Edward P. Molitor	New Jersey
Robert S. Phillips	North Carolina
Alfred Henry Weiters	Iowa
William Homer Wisely	Central States

1944

Name	*Member Association*
Alfred Edward Berry	Canadian
Van Porter Enloe	Georgia
Albert Legrand Genter	Maryland-Delaware
F. Wellington Gilcreas	New England
Charles A. Holmquist	New York
Dana Ewart Kepner	Rocky Mountain
Leon Benedict Reynolds	California
Wilson Waldo Towne	Dakota

1945

Name	*Member Association*
Howard Eugene Moses	Pennsylvania
George S. Russell	Missouri
Dario Travaini	Arizona
Frederick Holman Waring	Ohio
Joe Williamson, Jr.	Florida
Murray Alderson Wilson	Kansas

1946

Name	*Member Association*
E. J. M. Berg	Texas
Frank E. DeMartini	Federal
John R. Downes	New Jersey
Thomas J. Doyle	Michigan
John Henry Garner	I.S.P. (England)
Harold Benedict Gotaas	North Carolina
William P. Hughes	Pacific Northwest
Theodore R. Lovell	Iowa
George Martin	Central States

Convention Attendance Award

The Convention Attendance Award is in the form of a trophy which is presented annually to the Member Association which is credited with having aggregated the greatest number of man-miles in attending each Annual Meeting of the Federation. Permanent possession of the first trophy was won by the Central States Sewage Works Association in 1943, that organization having won the award for three consecutive years.

Central States Sewage Works Association	1941
Central States Sewage Works Association	1942
Central States Sewage Works Association	1943
Central States Sewage Works Association	1944
Central States Sewage Works Association	1946

Membership Prizes

Prizes for membership activity in its various Member Associations have been awarded by the Federation since 1943. The following Member Associations have received these prizes:

Association	*Year*
Federal Sewage Research Assn. and Central States Sewage Works Assn.	1943
Missouri Water and Sewerage Conf. and Central States Sewage Works Assn.	1944
Arizona Sewage and Water Works Assn. and Canadian Institute on Sewage and Sanitation	1945
Oklahoma Water and Sewage Conf. and Canadian Institute on Sewage and Sanitation	1946

Quarter Century Operators Club

The Quarter Century Operators Club is an informal group comprising Active or Corporate Members of any Member Association who had been engaged in sewage treatment works operation, on a full-time resident basis, twenty-five years prior to the date of their admission into the Club. The Club was created in 1941 under the sponorship of Frank Woodbury Jones, who serves as its registrar. The roster:

Charles C. Agar
Reuben A. Anderson
Harry M. Beaumont
George C. Behnke
Julius W. Bugbee
Raymond G. Case
E. Sherman Chase
Stuart E. Coburn
Morris M. Cohn
John R. Downes
Almon L. Fales
Arnold H. Goodman
Wm. C. Hamm
Charles C. Hommon
Frank W. Jones
Roy S. Lanphear
John V. Lewis
C. D. McGuire
Paul Molitor, Sr., (*Dec.*)
Arthur H. Niles
I. H. Nevitt
Wm. M. Piatt
Wm. A. Ryan
Theodore C. Schaetzle
Glenn Searls
John S. Simmerman
H. W. Streeter
S. L. Tolman

ANNUAL MEETINGS AND CONVENTIONS

Annual Meeting Number	*Location*	*Date*
1	Chicago, Illinois *	October 16, 1928
2	New York, New York *	January 18, 1929
3	New York, New York *	January 14, 1930
4	New York, New York *	January 22, 1931
5	New York, New York *	January 22, 1932
6	New York, New York *	January 19, 1933
7	New York, New York *	January 18, 1934
8	New York, New York *	January 18, 1935
9	New York, New York *	January 16, 1936
10	New York, New York *	January 22, 1937
11	New York, New York *	January 21, 1938
12	New York, New York *	January 20, 1939
13	New York, New York *	January 18, 1940
	Chicago, Illinois †	October 3–5, 1940
14	New York, New York *	January 15, 1941
	New York, New York †	October 9–11, 1941
15	Cleveland, Ohio ‡	October 22–24, 1942
16	Chicago, Illinois ‡	October 21–23, 1943
17	Pittsburgh, Pa. ‡	October 12–14, 1944
18	Chicago, Ill.*	October 17–18, 1945
19	Toronto, Ont., Can. ‡	October 7–9, 1946

* Annual business meeting of Board of Control.
† Convention of membership-at-large.
‡ Annual business meeting of Board of Control and convention of membership-at-large.

DIRECTORY OF COMMITTEES

1945–46

Constitutional Committees

(*See Article VI of By-Laws*)

EXECUTIVE COMMITTEE OF THE BOARD OF CONTROL

F. S. Friel, *Chairman*

Linden Stuart
Geo. S. Russell
Clyde C. Kennedy
David B. Lee

GENERAL POLICY COMMITTEE

The General Policy Committee studies and recommends to the Board of Control upon all matters of policy affecting the well-being and usefulness of the Federation and its Member Associations; matters of public relations; the advancement of and the professional and social status of members, and such other matters of similar nature as may be referred to it by the Board.

J. K. Hoskins, *Chairman*

A. H. Niles
John R. Downes
Dana E. Kepner
R. E. Fuhrman
M. LeBosquet, Jr.
D. E. Bloodgood

PUBLICATIONS COMMITTEE

The Publications Committee arranges the technical programs for the annual conventions of the Federation and has general supervision of all publications of the Federation.

F. W. Gilcreas, *Chairman*

Rolf Eliassen
Carl E. Green
C. C. Larson
F. W. Mohlman
F. M. Veatch
W. H. Wisely

ORGANIZATION COMMITTEE

The Organization Committee examines and reports to the Board on applications for membership in the Federation and endeavors to encourage the formation of new regional associations or conferences eligible for membership.

Earnest Boyce, *Chairman*

C. R. Compton
R. H. Suttie

Sewage Works Practice Committee

The Sewage Works Practice Committee reviews and directs for publication any resolution, report or publication which establishes professional or technical standards in the name of the Federation.

Morris M. Cohn, *Chairman*

Norval E. Anderson	C. W. Klassen
D. E. Bloodgood	L. W. Van Kleeck
R. F. Brown	Kerwin L. Mick
J. R. Downes	F. W. Mohlman
G. P. Edwards	A. H. Niles
F. W. Gilcreas	Langdon Pearse
H. F. Gray	Willem Rudolfs
K. V. Hill	F. M. Veatch
C. E. Keefer	W. H. Wisely

Subcommittee on Use of Sludge as Fertilizer

This subcommittee of the Sewage Works Practice Committee was assigned to compile a manual of practice on "Utilization of Sewage Sludge as Fertilizer." The assignment has been completed and Manual of Practice No. 2 was published under the above title in November, 1946.

A. H. Niles, *Co-Chairman*

Langdon Pearse, *Co-Chairman*

F. W. Gilcreas	T. C. Schaetzle
F. W. Mohlman	L. W. Van Kleeck
Willem Rudolfs	W. H. Wisely

Subcommittee on Occupational Hazards

This subcommittee of the Sewage Works Practice Committee has been assigned to compile a Manual of Practice on "Occupational Hazards in the Operation of Sewage Works." The manual has been completed and was distributed to the membership in December, 1944.

L. W. Van Kleeck, *Chairman*

S. H. Ash	Fred R. Ingram
Reuben F. Brown	L. L. Langford
Joseph Doman	L. E. West

Subcommittee on Air Diffusion

This subcommittee of the Sewage Works Practice Committee has been charged with the duty of producing a Manual of Practice on "Air Diffusion in Sewage Treatment." The manual is in preparation.

Norval E. Anderson, *Chairman*

A. J. Beck	W. F. Schade
G. P. Edwards	C. B. Townend
C. T. Mickle	

Subcommittee on Sewer Maintenance

This subcommittee of the Sewage Works Practice Committee has been directed to develop a Manual of Practice on "Maintenance of Sewers and Appurtenant Structures." The manual is in an early stage of preparation.

R. F. Brown, *Chairman*

Thos. B. Garry
W. H. Brown, Jr.
G. E. Fink
Grant Olewiler
R. L. Patterson
Henry Fitch
B. H. Grout
Roy E. Phillips
Richard Pomeroy
Robert P. Shea
John H. Brooks, Jr.
Forest Weber

Subcommittee on Chlorination of Sewage

This subcommittee of the Sewage Works Practice Committee has been assigned the development of a Manual of Practice on "The Use of Chlorine in Sewage Treatment." The manual is in a late stage of preparation.

F. W Gilcreas, *Chairman*

N. S. Chamberlain
A. E. Griffin
H. A. Faber

Subcommittee on Standardization of Units

This subcommittee of the Sewage Works Practice Committee has been assigned to develop an approved schedule of units to be used in the reporting of plant operation and laboratory data. A committee of about forty members is at work.

Willem Rudolfs, *Chairman*

Subcommittee on Trickling Filters

This subcommittee of the Sewage Works Practice Committee is engaged in the development of a Manual of Practice to be entitled "Trickling Filters—Their Characteristics and Loadings."

Kenneth V. Hill, *Chairman*

B. F. Hatch
W. S. Mahlie
Wm. E. Stanley

Subcommittee on Sewer Ordinances

This subcommittee of the Sewage Works Practice Committee has been assigned the preparation of a Manual of Practice concerning the regulation and control of the usage of public sewers. A preliminary draft of the manual is under review.

D. E. Bloodgood, *Chairman*

H. E. Babbitt
Fred J. Biele
R. F. Brown
M. M. Cohn
Charles A. Davis
C. E. Keefer
A. F. Lehman
A. H. Niles
B. A. Poole
J. L. Quinn
C. L. Siebert

Subcommittee on Sewage Works Accounting

Created in 1946 for the purpose of developing a manual of practice on accounting procedures for municipal sewage works functions, this subcommittee of the Sewage Works Practice Committee has just completed its organization.

F. M. Veatch, *Chairman*

G. J. Beiswanger
Charles A. Davis
Alfred A. Estrada
Roy E. Ritter
S. I. Zack

Subcommittee on Sanitary Districts

This sewage works practice subcommittee was created in 1946 to develop a manual on the formation and operation of sanitary districts. The subcommittee is now in process of organization.

C. W. Klassen, *Chairman*

Subcommittee on Sanitary Districts

This sewage works practice subcommittee has the function of assembling experience and data on paints and protective coatings used in sewage works, to be presented with recommendations in the form of a manual. The subcommittee was created in 1946 and is now being organized.

Kerwin L. Mick, *Chairman*

RESEARCH COMMITTEE

The Research Committee has the function of stimulating research work among the various Member Associations, and of co-operating with other organizations in the promotion of research.

Willem Rudolfs, *Chairman*

H. E. Babbitt
D. E. Bloodgood
G. P. Edwards
H. A. Faber
A. J. Fischer
H. Heukelekian
A. L. Genter
H. J. Miles
F. W. Mohlman
C. C. Ruchhoft
L. R. Setter
L. W. Van Kleeck

Special Committees

COMMITTEE ON AWARDS

The Committee on Awards was created by the Board of Control on October 11, 1941. Functions of the committee are to advise the Board on matters of award procedures and to make recommendations as to the annual winners of the Eddy, Gascoigne and Emerson Awards.

E. Sherman Chase, *Chairman*

Fred Merryfield
G. M. Ridenour
H. W. Streeter

Honorary Membership Committee

Authorized by the Board of Control on October 24, 1942, this committee comprises the President and four latest, living Past Presidents with the senior Past President as chairman. The committee reviews nominations for election to the grade of Honorary Member and makes recommendations to the Board on such nominations.*

Geo. J. Schroepfer, *Chairman*

F. S. Friel
A. M. Rawn
A. E. Berry
J. K. Hoskins

Finance Advisory Committee

The Finance Advisory Committee was created by the Board of Control on October 11, 1941, and has the duty of advising the Board and officers of the Federation in financial matters.

W. J. Orchard, *Chairman*

F. S. Friel
J. K. Hoskins

Operation Reports Committee

The Operation Reports Committee was created by the Board of Control on October 11, 1941, to provide for Federation recognition of outstanding operation reports. The committee is now engaged in developing the mechanics of an annual award for such outstanding reports.

H. E. Babbitt, *Chairman*

Wm. A. Allen
G. A. Hall

Operator's Qualification Committee

Authorized by the Board of Control on October 11, 1941, the Operator's Qualifications Committee is assigned to "establish minimal qualifications for operators of various classes of treatment works." The committee also has the duty of collecting and compiling data on present procedures in the licensing and certification of operators, for reference to Member Associations.

L. W. Van Kleeck, *Chairman*

Wm. A. Allen
E. P. Molitor

Industrial Wastes Committee

The Industrial Wastes Committee was created by the Board of Control on October 23, 1943, for the purpose of developing interest in this important field and to direct a program whereby the Federation may be of service in industrial waste problems.

F. W. Mohlman, *Chairman*

D. E. Bloodgood
H. W. Gehm
Wm. J. O'Connell
L. F. Oeming
Wm. S. Wise

* See This Journal, 16, 1, 196 (January, 1944).

Nominating Committee

The special Nominating Committee was created by the Board of Control on October 9, 1946, to function in an advisory capacity to the Election Committee. The Nominating Committee is to comprise the last five living Past Presidents, with the senior Past President as chairman.

C. A. Emerson, *Chairman*

A. E. Berry
J. K. Hoskins
A. M. Rawn
G. J. Schroepfer

Quarter Century Operators Club Committee

The special Quarter Century Operators Club Committee was created by the Board of Control on October 9, 1946. It is the function of this Committee to establish eligibility requirements, process membership applications, maintain the roster and supervise the activities of the Quarter Century Operators Club.

Frank W. Jones, *Chairman*

Stuart E. Coburn
Harold W. Streeter

Legislative Analysis Committee

The Legislative Analysis Committee was created by the Board of Control on October 17, 1945, to study legislation pertinent to the interests of the Federation and to serve the Board in advisory capacity.

Ralph E. Fuhrman, *Chairman*

Earnest Boyce
L. D. Matter
C. G. Gillespie
W. B. Hart
Morris M. Cohn
W. M. Ehlers
L. F. Warrick
R. L. Winget

Joint Committees With Other Associations

Committee on Standard Methods of Sewage and Industrial Wastes Analysis

Created by the Board of Control on January 22, 1931, the Committee on Standard Methods of Sewage Analysis has functioned with committees of the American Water Works Association and American Public Health Association in the production of the Eighth Edition of the volume *Standard Methods of Water and Sewage Analysis.* The section on sewage analysis for the Ninth Edition was completed by the committee in 1943.

W. D. Hatfield, *Chairman*

G. E. Symons
S. E. Coburn
D. E. Bloodgood
A. J. Fischer
F. W. Gilcreas
R. D. Hoak
E. F. Hurwitz
Keeno Fraschino
W. S. Mahlie
H. Heukelekian
G. P. Edwards
E. W. Moore
M. Starr Nichols
Richard Pomeroy
C. C. Ruchhoft
Willem Rudolfs
H. W. Gehm
R. F. Weston

Committee on Sewage Works Nomenclature

The Committee on Sewage Works Nomenclature was created by the Board of Control on January 22, 1937, to function with similar committees of the American Society of Civil Engineers and American Public Health Association. This Joint Committee on Definition of Terms Used in Sewerage and Sewage Disposal Practice is now engaged in the compilation of a "Glossary of Water and Sewage Control Engineering," in conjunction with the Joint Committee on Definition of Terms Used in Water Works Practice, which comprises the American Society of Civil Engineers, American Public Health Association and American Water Works Association.

C. J. Velz, *Chairman*

C. E. Keefer
C. A. Emerson

Committee on Water and Sewage Works Development

The Committee on Water and Sewage Works Development was organized in 1943 to promote the planning of water and sewage works and to encourage the inclusion of such projects in postwar planning programs. The committee, temporarily inactivated, comprises representatives of the Water and Sewage Works Manufacturers Association, American Water Works Association, New England Water Works Association and the Federation of Sewage Works Associations. Federation representatives are:

C. A. Emerson
G. J. Schroepfer

Special Convention Committees

Convention Management Committee

The function of this committee is to supervise details of the management of the Annual Meetings of the Federation.

W. J. Orchard, *Chairman*

F. S. Friel
W. H. Wisely
C. C. Kennedy
A. T. Clark

Meeting Place Committee

This committee reviews invitations received for the Annual Meetings of the Federation and makes recommendations to the Board of Control in regard to the time and place of such meetings.

F. S. Friel, *Chairman*

J. K. Hoskins
G. S. Russell
W. H. Wisely
W. C. Sherwood
A. E. Paxton
A. T. Clark

Publicity and Attendance Committee

The function of this committee is to prepare publicity releases in connection with the Annual Meetings of the Federation and to direct the distribution of such material.

L. H. Enslow, *Chairman*

E. J. Cleary
M. M. Cohn
W. S. Foster
A. Prescott Folwell
J. P. Russell
J. A. Daly

SUMMARY OF MEMBERSHIP

(As at December 31, 1946)

Federation Members

Honorary Members	8
Associate Members	77
Member Associations	29
Active Members	3,646
Alternate Active Members	31
Corporate Members	26

Net Membership of Member Associations *

Member Association	Active	Alternate Active	Corporate	Total
Argentina	—	—	—	—
Arizona	32	—	—	32
Arkansas	4	—	—	4
California	319	7	—	326
Canadian Inst.	317	—	—	317
Central States	570	—	13	583
Dakota	39	—	—	39
Federal	126	—	—	126
Florida	76	—	—	76
Georgia	51	—	—	51
Iowa	41	—	—	41
ISE (Eng.)	34	—	—	34
ISP (Eng.)	121	—	—	121
Kansas	21	—	—	21
†Kentucky-Tennessee	—	—	—	—
Maryland-Delaware	35	—	—	35
Michigan	120	17	—	137
Missouri	55	—	—	55
Montana	32	—	2	34
New England	225	—	—	225
New Jersey	89	—	—	89
New York	542	7	2	551
North Carolina	50	—	—	50
Ohio	189	—	1	190
Oklahoma	35	—	—	35
Pacific Northwest	110	—	—	110
Pennsylvania	281	—	8	289
Rocky Mountain	62	—	—	62
Texas	70	—	—	70
Totals	3,646	31	26	3,703

* Not including Dual Members.

† New Member Association. Admitted to Federation on October 30, 1946.

Directory of Members

December 31, 1946

MEMBER ASSOCIATIONS

Argentina Society of Engineers, Sanitary Engineering Division (Affiliated 1936).

Territory: Republic of Argentina.
President: Emelio E. Sisto; *Director:* E. B. Besselievre; *Secretary:* Julio Caviechia, Centro Argentino De Ingenieros, Buenos Aires, Republica Argentina, South America.

Arizona Sewage and Water Works Association—Sewage Works Section (Affiliated 1928).

Territory: State of Arizona.
President: R. M. Cushing; *First Vice-President:* Harold Yost; *Second Vice-President:* John Rauscher; *Director:* A. L. Frick, Jr.; *Secretary-Treasurer:* G. W. Marx, Division of Sanitary Engineering, Arizona State Department of Health, Phoenix, Ariz.

Arkansas Water and Sewage Conference—Sewage Works Section (Affiilated 1946).

Territory: State of Arkansas.
Chairman: W. R. Spencer; *Vice-Chairman:* J. R. Pierce; *Director:* F. L. McDonald; *Secretary-Treasurer:* Harrison Hale, 118 Chemistry Bldg., Fayetteville, Ark.

California Sewage Works Association (Affiliated 1928).

Territory: State of California.
President: G. A. Parkes; *First Vice-President:* H. L. May; *Second Vice-President:* Ray L. Derby; *Director:* Blair I. Burnson; *Secretary-Treasurer:* A. G. Pickett, 700 Union League Bldg., Los Angeles, Calif.

Canadian Institute on Sewage and Sanitation (Affiliated 1933).

Territory: Dominion of Canada.
President: Nicol MacNicol; *Vice-President:* G. H. Richards; *Director:* R. J. Desmarais; *Secretary-Treasurer:* A. E. Berry, Ontario Department of Health, Parliament Buildings, Toronto 8, Ontario, Canada.

Central States Sewage Works Association (Affiliated 1928).

Territory: States of Illinois, Indiana, Wisconsin and Minnesota.
President: E. J. Beatty; *First Vice-President:* P. W. Riedesel; *Second Vice-President:* Carl B. Carpenter; *Third Vice-President:* L. S. Kraus; *Director:* C. C. Larson; *Secretary-Treasurer:* J. C. Mackin, P. O. Box 1228, Madison 1, Wisconsin.

Dakota Water and Sewage Works Conference—Sewage Works Sections (Affiliated 1936).

North Dakota Section.

Territory: State of North Dakota.
President: John B. Kleven; *Vice-President:* Harley G. Quam; *Director:* Roy G. Spieker; *Secretary-Treasurer:* Jerome H. Svore, Division of Sanitary Engineering, State Department of Health, Bismarck, North Dakota.

South Dakota Section.

Territory: State of South Dakota.
President: Ralph Reed; *Vice-President:* Richard Curtis; *Director:* Roy G. Spieker; *Secretary-Treasurer:* W. W. Towne, Division of Sanitary Engineering, State Board of Health, Pierre, South Dakota.

Federal Sewage Research Association (Affiliated 1930).

Territory: Federal employees wherever stationed.
President: V. G. MacKenzie; *Vice-President:* V. B. Lamoureux; *Director:* M. LeBosquet, Jr.; *Secretary-Treasurer:* Carl E. Schwob, USPHS, 2000 Massachusetts Ave., N.W., Washington 25, D. C.

Florida Sewage Works Association (Affiliated 1941).

Territory: State of Florida.
President: B. F. Borden, Jr.; *Vice-President:* Albert L. McGregor; *Director:* David B. Lee; *Secretary-Treasurer:* J. R. Hoy, 402 Hildebrandt Bldg., Jacksonville, Fla.

Georgia Water and Sewage Association (Affiliated 1936).

Territory: State of Georgia.
President: Comer Turley; *First Vice-President:* B. L. Coburn; *Second Vice-President:* D. H. Hurst; *Director:* H. A. Wyckoff; *Secretary-Treasurer:* Van P. Enloe, RFD No. 5, Box 363, Atlanta, Ga.

Iowa Sewage Works Association (Affiliated 1928).

Territory: State of Iowa.
President: Charles Alexander; *Vice-President:* Leo Holteamp; *Director:* John W. Pray; *Secretary-Treasurer:* Robert D. Mott, 30 Valley Ave., Iowa City, Iowa.

Institute of Sewage Purification—England (Affiliated 1932).

Territory: British Empire.
President: Dr. E. J. Hamlin; *Director:* J. H. Garner; *Federation Contact Member:* J. H. Garner; 28 Aberford Road, Wakefield, Yorks.

Institution of Sanitary Engineers—England (Affiliated 1932).

Territory: British Empire.
President: Gordon S. McDonald; *Director:* Guy Howard Humphreys; *Secretary:* Edward H. Webb, 118 Victoria St., Westminster, S.W. 1, London, England.

Kansas Sewage Works Association (Affiliated 1935).

Territory: State of Kansas.
President: Murray A. Wilson; *Vice-President:* Neal Harr; *Director:* P. E. Kaler; *Secretary-Treasurer:* Paul D. Haney, c/o State Board of Health, Room 2, Marvin Hall, University of Kansas, Lawrence, Kansas.

Kentucky-Tennessee Industrial Wastes and Sewage Works Association (Affiliated 1946).

Territory: States of Kentucky and Tennessee.
Chairman: F. C. Dugan; *Vice-Chairman:* Julian R. Fleming; *Director:* James Ellis; *Secretary-Treasurer:* R. Paul Farrell, 420 Sixth Ave., North, Nashville, Tenn.

Maryland-Delaware Water and Sewerage Association—Sewage Works Section (Affiliated 1928).

Territory: States of Maryland and Delaware.
President: Clarke Gardner; *First Vice-President:* J. W. Engle; *Second Vice-President:* R. C. Willson; *Director:* Ralph E. Fuhrman; *Secretary-Treasurer:* Miss E. V. Gipe, State Department of Health, 2411 N. Charles St., Baltimore, Md.

Michigan Sewage Works Association (Affiliated 1930).

Territory: State of Michigan
President: R. A. Greene; *Vice-President:* Stanley Bower; *Director:* W. F. Shephard; *Secretary-Treasurer:* R. J. Smith, 545 Elizabeth St., East Lansing, Mich.

Missouri Water and Sewerage Conference—Sewage Works Section (Affiliated 1929).

Territory: State of Missouri.
Chairman: Melvin P. Hatcher; *Vice-Chairman:* Rodger C. Higgins; *Director:* William Q. Kehr; *Secretary-Treasurer:* Warren A. Kramer, c/o State Office Bldg., Jefferson City, Mo.

Montana Sewage Works Association (Affiliated 1944).

Territory: State of Montana.
Chairman: Kenneth Chrysler; *Vice-Chairman:* K. J. Winebrenner; *Director:* J. M. Schmidt; *Secretary-Treasurer:* H. B. Foote, Division of Sanitary Engineering, State Board of Health, Helena, Montana.

New England Sewage Works Association (Affiliated 1929).

Territory: States of Maine, New Hampshire, Vermont, Massachusetts, Connecticut and Rhode Island.
President: Thomas R. Camp; *First Vice-President:* LeRoy W. Van Kleeck; *Second Vice-President:* Walter H. Brown, Jr.; *Director:* LeRoy W. Van Kleeck; *Secretary-Treasurer:* Walter E. Merrill, State Dept. of Public Health, 511A State House, Boston, Massachusetts.

New Jersey Sewage Works Association (Affiliated 1942).

Territory: State of New Jersey.
President: L. J. Fontenelli; *First Vice-President:* L. E. West; *Second Vice-President:* John Struss; *Director:* P. N. Daniels; *Secretary-Treasurer:* Michael S. Kachorsky, P. O. Box 283, Manville, N. J.

New York State Sewage Works Association (Affiliated 1930).

Territory: State of New York.
President: Uhl T. Mann; *Vice-President:* A. G. Martin; *Director:* E. J. Smith; *Secretary-Treasurer:* A. F. Dappert, State Department of Health, Albany, N. Y.; *Assistant Secretary:* A. W. Eustance; *Assistant Treasurer:* J. C. Brigham.

North Carolina Sewage Works Association (Affiliated 1929).

Territory: State of North Carolina.
Chairman: J. A. English; *Vice-Chairman:* W. M. Franklin; *Director:* George S. Rawlins; *Secretary-Treasurer:* Geo. S. Moore, P. O. Box 125, Albermarle, North Carolina.

Ohio Conference on Sewage Treatment (Affiliated 1932).

Territory: State of Ohio.
Chairman: L. C. Huffman; *Vice-Chairman:* L. B. Barnes; *Director:* A. H. Niles; *Secretary-Treasurer:* G. A. Hall, 302 Department of State Bldg., Columbus, Ohio.

Oklahoma Water and Sewage Conference—Sewage Works Section (Affiliated 1929).

Territory: State of Oklahoma.
President: Cecil Harrison; *Vice-President:* Hugh Devore; *Director:* E. R. Stapley; *Secretary-Treasurer:* H. J. Darcey, State Department of Health, Oklahoma City, Okla.

Pacific Northwest Sewage Works Association (Affiliated 1933).

Territory: States of Washington, Oregon and Idaho.
President: C. M. Howard; *First Vice-President:* H. C. Clare; *Second Vice-President:* K. H. Spies; *Director:* M. S. Campbell; *Secretary-Treasurer:* Wm. P. Hughes, City Engineer's Office, Lewiston, Idaho.

Pennsylvania Sewage Works Association (Affiliated 1928).

Territory: State of Pennsylvania.
President: William J. Murdock; *First Vice-President:* Norman G. Young; *Second Vice-President:* Charles H. Young; *Director:* L. D. Matter; *Secretary-Treasurer:* Bernard S. Bush, Pennsylvania Department of Health, Kirby Health Center, Wilkes-Barre, Pa.

Rocky Mountain Sewage Works Association (Affiliated 1936).

Territory: States of Wyoming, Colorado and New Mexico.
President: N. P. Nielsen; *Vice-President:* H. G. Watson; *Director:* W. V. Leonard; *Secretary-Treasurer:* Carroll H. Coberly, 1441 Welton St., Room 329, Denver 2, Colorado.

Texas Sewage Works Section (Affiliated 1928).

Territory: State of Texas.
Chairman: L. C. Billings; *Vice-Chairman:* J. H. Sorrels; *Director:* E. J. M. Berg; *Secretary-Treasurer:* V. M. Ehlers, 410 E. 5th St., Austin, 2, Texas; *Assistant Secretary-Treasurer:* Mrs. E. H. Goodwin.

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Mohlman, Dr. Floyd W. (1944), 910 S. Michigan Ave., Chicago 5, Ill.

Moses, Howard E. (1943), 1522 N. Second St., Harrisburg, Pa.

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Rudolfs, Dr. Willem (1945), Short Course Bldg., Agricultural Experiment Station, New Brunswick, N. J.

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American Brass Co., Waterbury, Conn.

American Cast Iron Pipe Co., Birmingham, Ala., Rep. E. L. Gilder.

American City Magazine, 470 Fourth Avenue, New York, N. Y., Rep. Edgar J. Buttenheim, Pres. & Mgr.

American Concrete Pipe Assn., 228 N. LaSalle St., Suite 1033, Chicago 1, Ill., Rep. Howard F. Peckworth, Managing Dir.

American Well Works, Aurora, Ill., Rep. J. D. Walker, Sanitary Div.

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Automatic Control Co., 1005 University Ave., St. Paul 4, Minn., Rep. J. S. Williams.

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Chapman Valve Manufacturing Co., 203 Hampshire St., Indian Orchard, Mass.

Chicago Pump Company, 2300 Wolfram St., Chicago, Ill., Rep. Milton Spiegel, Vice-Pres. & Gen. Mgr.

Clay Products Assn., 111 W. Washington St., Chicago 2, Ill., Rep. J. D. Cook, Secy.

Climax Engineering Co., Chicago Office, 111 W. Monroe St., Room 922, Chicago 3, Ill., Rep. E. D. West, Mgr.

Crane Company, 836 S. Michigan Ave., Chicago 5, Ill., Rep. G. W. Hauck, Mgr., Eng. Sales Section

DeLaval Steam Turbine Co., Trenton 2, N. J., Rep. H. V. Petersen, Sales Mgr.

Dickey Clay Mfg. Co., W. S., 607 Commerce Trust Bldg., Kansas City, Mo., Rep. A. G. Frerking, Vice Pres.-Sales Mgr.

Dorr Co., Inc., 570 Lexington Ave., New York, N. Y.

Dow Chemical Co., Midland, Mich., Rep. W. A. Melching.

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Electro Rust-Proofing Co., 1026 Wayne St., Dayton 10, Ohio, Rep. E. H. Ingle, Gen. Mgr.

Engineering News-Record, 330 W. 42nd St., New York, N. Y.

Everson Manufacturing Co., 214 W. Huron St., Chicago 10, Ill., Rep. R. B. Everson, Pres.

Fairbanks, Morse & Co., 80 Broad St., New York 4, N. Y., Rep. Charles J. Prestler, Manager Pump Sales.

Flexible Sewer-Rod Equipment Co., 9059 Venice Blvd., Los Angeles, Calif., Rep. Peter L. Ciacco, Mgr.

Foxboro Company, Neponset Avenue, Foxboro, Mass.

Gale Oil Separator Co., Inc., 52 Vanderbilt Ave., New York City, Rep. Wm. A. Gehle, Pres.

General Chemical Co., 3357 W. 47th Place, Chicago 32, Ill., Rep. L. I. Birdsall, Technical Service Div.

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Glamorgan Pipe & Foundry Co., Lynchburg, Va., Rep. John D. Capron.

Green Bay Fdy. & Machine Wks., 401 S. Broadway, Green Bay, Wis., Rep. James P. North, Pres.

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Lynchburg Foundry Company Lynchburg, Va., Rep. W. Ray Odor.

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Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa., Rep. N. R. Chillingworth, Sales Statistical Dept.

Mueller Company, 512 W. Cerro Gordo St., Decatur, Ill.

National Water Main Cleaning Co., 30 Church St., New York, N. Y., Rep. J. A. Frank, Pres. & Gen. Mgr.

Nichols Engineering & Research Corp., 60 Wall Tower, New York, N. Y., Rep. R. W. Rowen, Vice-Pres.

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Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill., Rep. L. E. Rein, Pres.

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Pittsburgh Pipe Cleaner Co. of New York, 3004 Woolworth Bldg., New York 7, N. Y., Rep. Kyle I. Robinson, Pres.

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Public Works Magazine, 310 E. 45th St., New York, N. Y.

Public Works News, 185 Madison Ave., New York 16, N. Y., Rep. John K. Gurwell, Editor

Quigley Company, Inc., 527 Fifth Ave., New York City 17, N. Y., Rep. R. A. Trefethen, Adv. Mgr.

Royer Foundry & Machine Co., 158 Pringle St., Kingston, Pa., Rep. S. B. Davies, Pres. & Gen. Mgr.

Sewage Works Engineering, 24 W. 40th St., New York, N. Y., Rep. Karl M. Mann.

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Water and Sewage Works, 155 E. 44th St., New York, N. Y.

Wood Co., R. D., Public Ledger Bldg., Independence Square, Philadelphia 5, Pa.

Worthington Pump & Machinery Corp., Harrison, N. J.

Yeomans Bros. Co., 1433 Dayton St., Chicago, Ill., Rep. Chas. Yeomans, Pres. & Treas.

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Arkansas Water and Sewage Conference—Sewage Works Section

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Albers, J. C., California
Albertson, J. G., New York
Albrecht, Robert H., New York
Albright, Philip N., Texas
Alcorn, James D., California
Alden, Clifford E., New England
Alden, John W., Maryland-Delaware
Alderman, Frank E., California
Aldred, H., England (I. S. P.)
Aldrich, Ellwood H., New York
Aldrich, Lloyd, California
Aldridge, Frederick F., Federal
Alexander, Louis J., California
Alikonis, J. J., Central States
Alk, Lewis C., Central States
Allegheny County Sanitary Authority, Att'n: F. J. Laboon (Corporate), Pennsylvania
Allen, Edward H., Florida
Allen, F. W., England (I. S. P.)
Allen, T. E., California
Allen, Wm. A., California
Allin, Claud R., California
Allin, John H., California
Allison, S. L., Texas
Alter, Amos J., Federal
Aluminum Co. of America, Associate, Att'n: F. J. Close
American Brass Co., Associate,
American Cast Iron Pipe Co., Associate, Att'n: E. L. Gilder
American City Magazine, Associate, Att'n: Edgar J. Buttenheim
American Concrete Pipe Assn., Associate, Att'n: Howard F. Peckworth
American Enka Corp., North Carolina
American Viscose Corp. (Corporate), Pennsylvania
American Well Works, Associate, Att'n: J. D. Walker
Ames, City of, Iowa
Amramy, Aaron, Central States
Anaya, Marvin, California
Andersen, C. Geo., New York
Anderson, C. S., Canada
Anderson, Geo. H., Central States
Anderson, Lewis D., Federal
Anderson, Norman W., California
Anderson, Norval E., Central States
Anderson, R. A., Michigan
Anderson, R. V., Canada
Anderson, Raymond E., Central States
Anderson, Sam, Central States
Anderson, Stuart H., Federal
Anderson, Virgil, Michigan
Anderson, Walter C., New England
Anderson, Wendell D., Georgia
Andrews, John, Federal
Andrews, L., England (I. S. P.)
Andrews, R. U., Texas
Angas, Robert M., Florida
Angell, J. M., Jr., New York
Anthony, Robert J., New England
Antl, John C., Central States
Appel, A. A., California
Arbogast, Joseph H., Central States
Archer, E. T., Missouri
Argo, John W., Canada
Armco Drainage Products Assn., Associate, Att'n: W. H. Spindler
Armeling, Geo. K., Maryland-Delaware
Armour, J. G., Canada
Armour Leather Co. (Corporate), Pennsylvania
Armstrong, C. G. R., Canada
Armstrong, Charles, New Jersey
Arnold, E. L., Montana
Arnold, Earl H., North Dakota (Dual-Federal)
Arnold, G. E., California (Dual-Federal)
Arnold, Roy M., Montana
Arrowsmith, E. H., England (I. S. P.)
Artese, Philip, New York
Artist, L. J., England (I. S. P.)
Aschenbrenner, Paul F., Central States
Ash, Simon H., Federal
Ashby, E. Hamilton, England (I. S. E.)
Ashdown, Walter L., Central States
Ashley, John H., California
Aslamidis, A., England (I. S. E.)
Atkins, C. H., Federal
Atkinson, V. E., Texas
Attwell, Walter G., California
Automatic Control Co., Associate, Att'n: J. S. Williams
Averill, Walter A., Pacific Northwest
Avery, James, Canada
Avery, N. C., New England
Axe, Earl J., New Jersey
Ayers, Lewis S., Pennsylvania

Babbitt, H. E., Central States
Babcock, Irving, New York
Baber, John E., Florida
Bachmann, Frank, New York
Backherms, A. B., Ohio
Backmeyer, David, Central States
Bacon, Vinton W., California
Badger, Irvin S., New York
Baer, Arlie, Central States
Baetz, C. O., Central States
Baffa, John J., New York
Bahr, Raymond F., New England
Bailey, H. M., Canada
Bailey, J. Kenneth, North Carolina
Bailey, J. W., Ohio
Bailey, S. C., Pennsylvania
Baillie, E. P., Central States
Bainbridge, David W., Pennsylvania
Baird, Chas. O., Jr., New England
Baird, Earle E., Florida
Baird, E. M., Canada
Baity, H. G., North Carolina
Baker, G. H., Canada
Baker, Stanley L., Pacific Northwest
Bale, Harvey E., Pennsylvania
Balfour, D. & Sons, England (I. S. P.)
Ball, Oliver V., Canada
Balmer, Robert R., Jr., New England
Balsom, E. V., England (I. S. E.)
Bamford, J. H., Pacific Northwest
Bandy, W. A., Texas
Banister, A. W., Central States
Banks, Harvey O., California
Bankson, Ellis E., Pennsylvania
Banta, A. Perry, California
Bantz, Burwell, Pacific Northwest
Barber, Ben C., Ohio
Barbour, Frank A., New England
Barclay W. G., England (I. S. E.)
Bardes, Daniel, New York
Bardet, Paul E., New York
Bargman, R. D., California
Barker, J. Conrad, Jr., Pennsylvania
Barker, Stanley T., New York
Barklage, O. F., Iowa
Barnard, Archer F., California
Barnes, Chas. R., Pennsylvania
Barnes, Geo. E., Ohio
Barnes, L. B., Ohio
Barnett, G. R., Central States
Barnett, M. L., Florida
Barney, J. W., Pacific Northwest
Barngrover, Lester, Oklahoma
Barnhart, Thomas F., Pennsylvania
Barnhill, John T., Central States
Barnhill, Kenneth G., New York
Baron, A. R., Missouri
Barraclough, D. H., England (I. S. P.)
Barrett, Cecil H., Pennsylvania
Barrett, J. O., Ohio
Barrett, J. S., California
Barrick, M. J., Pennsylvania
Barron, James L., New York
Barrow, R. E., Texas
Barry, Lester S., California
Barry, W. Vincent, New England
Barstow, E. D., Ohio
Bartholomew, David Wm., New England
Barton, Ben H., Ohio
Barton, Jas. M., New York
Bartow, Edward, Iowa
Bartow, Leslie W., Pacific Northwest
Bartsch, A. F., Central States
Bartz, Erwin A., Central States
Bash, Gail, California
Bass, J. H., Ohio
Bates, Riley C., Central States
Bates, R. D., New York
Baton, Warren, Pennsylvania
Battey, Everett M., New England
Battles, L. C., Montana
Bauer, Carl, Ohio
Bauer, Henry W., New England
Baulsir, Chas. P., New York
Baum, H. J., Pennsylvania
Bavone, A. L., Dakota
Baxter, R. M., Central States
Baxter, R. R., Central States
Bayard, G. A., Canada
Baylis, John R., Central States
Beamesderfer, Jas. A., Pennsylvania
Bean, Elwood L., Pennsylvania
Bean, H. W., Oklahoma
Beard, Arthur H., Jr., Central States
Beard, Elmer H., New England
Beardsley, C. W., California
Beaton, R. H., California
Beatty, E. J., Central States
Beaudoin, Robert E., Central States
Beaumont, H. M., Pennsylvania
Beavin, B. E., Maryland-Delaware
Beck, A. J., Central States
Becker, Carlton H., Central States
Becker, Fred G., California
Becker, John, New York
Becker, Philip G., Jr., Texas
Beckett, Richard C., Pennsylvania
Beckett, W. A., Central States
Beckman, LeRoy J., Central States
Bedker, Oscar, Central States
Bejcek, Otto J., Arizona
Belaskas, A. J., Central States
Belknap, A., Oklahoma
Bell, E. Arthur, New Jersey
Bell, Frank V., Canada
Bell, Fred A., Canada
Bell, John W., California
Belt, Elmer B., California
Beltz, Harold H., Michigan
Bender, Dwight O., Central States
Benham, Webster L., Oklahoma
Bennawit, Wm., B., Pennsylvania
Benner, Hugh A., Michigan
Bennett, Carl, Rocky Mountain
Bennett, Christopher F., New York
Bennett, Leon, Oklahoma
Bennett, Richard, Arizona
Bennett, S. G., California
Bennett, W. W., England (I. S. P.)
Benson, Sidney T., New York

Berg, E. J. M., Texas
Bergen, C. B., New Jersey
Berger, Bernard B., Federal
Bergin, Francis T., New England
Bergman, O. O., Central States
Berkeley, Garnet L., Canada
Berkeley, Winston H., Pacific Northwest
Bernard, G. E., Canada
Bernauer, Geo. F., Central States
Bernhardt, Carl J., New York
Berntsen, Bertel, Central States
Berrigen, Thomas A., New England
Berry, A. E., Canada
Berry, Ray E., California
Berry, Robert D., Pennsylvania
Bers, G. D., Central States
Berton, C. J., New York
Besozzi, Leo, Central States
Besselievre, Edmund C., New York
Bessinger, B. A., Ohio
Best, Robert B., New York
Beswick, G., England (I. S. P.)
Bethel, John S., New England
Beukema, Robert, Michigan
Bevacqua, Joseph, New York
Bevan, John G., New York
Beveridge, Ben H., California
Bevington, Warren C., Central States
Bezy, Maurice G., Florida
Bhoota, B. V., New York
Bidwell, Milton H., New York
Biele, Arthur V., Central States
Biele, F. J., New York
Biggs, Merrill, Arizona
Biladeau, Archie L., Pacific Northwest
Billings, C. H., Jr., Texas
Billings, L. C., Texas
Binger, Walter D., New York
Bingley, W. M., Maryland-Delaware
Bird, T. A., Canada
Birdsall, L. I., Central States
Birkeness, O. T., Central States
Bishop, H. N., California
Bjelajac, Vaso, Central States
Black, D. T., Canada
Black, Hayse H., Central States
Black & Veatch (Corporate), Central States
Blackett, Joseph P., New England
Blackstone, W. Wheeler, Texas
Blaha, J. A., Michigan
Blaisdell, Edwin N., New York
Blakeley, Loren E., California
Blew, Michael J., Federal
Blinder, Jacob W., New York
Blizard, W. E., England (I. S. E.)
Bloem, Herman, Ohio
Blood, Lloyd, New York
Bloodgood, Donald E., Central States
Bloom, Enos E., Central States
Board, Leonard M., Federal
Boardman, John, Pennsylvania
Boardman, Wm. Hunter, Jr., Pennsylvania
Bochoven, Clarence, Ohio
Boeke, Harley C., Central States
Boes, Robert J., Central States
Bogardus, Theodore S., Pennsylvania
Bogema, Marvin, Central States
Bogert, C. L., New York
Bogost, Meyer S., Central States
Bogren, Geo. G., New England
Bolde, Abraham C., New England
Bolenius, Robert M., Pennsylvania
Boles, John, Central States
Bolin, R. R., Jr., California
Bollinger, Edward, Ohio
Bolton, J. F., England (I. S. P.)
Bolton, Wm. M., New England
Bond, Eugene L., New England
Bond, Philip E., New England
Bond, R. G., Iowa
Bongiovanni, Jose P., Florida
Boni, Anthony, New York
Bonner, Robert, Ohio
Bonner, Tom F., Rocky Mountain
Bontempo, Dominic, Pennsylvania
Booker, Warren H., Rocky Mountain
Booth, A. R., Canada
Boothe, B. K., Canada
Borden, B. F., Florida
Borchardt, Jack S., Central States
Border, Wm. R., Montana
Boreiszo, Joseph F., New Jersey
Borgford, T. B., Canada
Boriss, Marion E., New York
Borland, Victor J., California
Borquist, E. S., Arizona
Bosch, Herbert M., Central States
Both, Jack, Canada
Bothwell, John I., California
Bow, Wilson F., Pacific Northwest
Bowan, Walter J., Central States
Bowe, Thomas F., New York
Bowen, L. C., Georgia
Bowen, M. R., California
Bower, Stanley M., Michigan
Bowering, R., Canada
Bowers, Tony C., Michigan
Bowler, Edmond Wesley, New England
Bowlin, F. C., Rocky Mountain
Bowlus, Fred D., California
Bowman, C. R., Texas
Bowman, G. T., California
Bowmanville, Corp. of the town of, Canada
Bowness, G. W., Canada
Bowron, Fletcher, California
Boyce, Earnest, Michigan
Boyce, Ralph E., New York
Boyd, Geo. E., New York
Boyd, J. Walter, Michigan
Boyer, Burleigh Bond, California
Boyle, J. R. Lester, California
Bradley, Whitney L., Canada
Bradney, Leland, Central States
Bragstad, R. E., Central States
Bradner, Basil E., New York
Bragg, Robert E., Central States
Bragg, J. M., Georgia
Brakenridge, Chas., Canada
Braker, R. C., Ohio
Brallier, Paul S., New York
Brandenburg, Kenneth B., New York
Brandis, F. E., Montana
Brannock, D. York, North Carolina
Brassey-Edwards, S., England (I. S. E.)
Brearley, Edgar, Canada
Breen, Joe, Canada
Brennan, Ralph F., Florida
Brenner, Kenneth, New York
Brensley, A. A., Central States
Brereton, W. P., Canada
Brewer, E. E., Pacific Northwest
Brickenden, F. M., Canada
Brickley, J., England (I. S. P.)
Bridgman, R. J., Canada
Briggs, Raymond J., Pacific Northwest
Brigham, John C., New York
Brigham, John C., Jr., New York
Bright, John H., Federal
Brinck, Claiborne W., Jr., Montana
Britt, C. E., Ohio
Britton, Benj. A., Jr., New England
Broadmann, D. J., Georgia
Broderick, John T., New England
Brody, James, Central States
Brook, David W., Central States
Brook, Harry L., Central States
Brooks, James K., Central States
Brooks, John H., Jr., New England
Brower, James, Central States
Brower, J. Singleton, New York
Brown, Beverley J., Canada
Brown, Edward S., Jr., New England
Brown, Fred W., California
Brown, Glenn V., Pennsylvania
Brown, James G., Michigan
Brown, James M., Jr., New York
Brown, K. V., Canada
Brown, Kenneth W., California
Brown, Reuben F., California
Brown, Ronald, New Jersey
Brown Stuart, Georgia
Brown, Wade Gillies, North Carolina
Brown, Walter H., Jr., New England
Brown, W. Fillingham, England (I. S. E.)
Browne, F. G., Canada
Browne, Floyd G., Ohio
Brownridge, F. B., Canada
Brug, C. J., California
Brunn, Philip A., Jr., Pennsylvania
Brunner, Paul L., Central States
Brunty, C. E., California
Bryan, A. C., Texas
Bryan, John G., New Jersey
Bryant, C. T., Ohio
Bryant, W. G., Georgia
Bryce, W. F. M., Canada
Buchecker, A. I., Pacific Northwest
Buck, Geo. H., New York
Buck, Robinson D., New England
Buck, Ross J., Central States
Buckley, E. J., Canada
Buckley, Thomas, Pennsylvania
Budd, Edward G. Mfg. Co. (Corporate), Pennsylvania
Buehler, Herman, Ohio
Bugbee, Julius W. (Honorary) New England
Bugbee, Raymond C., New England
Builders-Providence, Inc. Associate, Att'n: C. G. Richardson
Bull, C. C., Ohio
Bullen, Paul W., Central States
Bullock, C. C., Arizona
Bulot, Francis H., California
Bunker, F. L., North Carolina
Burack, W. D., New Jersey
Buraglia, A. M., Canada
Burden, Harry P., New England
Burden, Robert P., New England
Burdick, Geo. E., New York
Burdoin, Allen J., New England
Burger, A. A., Ohio
Burger, Arnold W., Central States
Burgeson, J. H., Central States
Burgess, Harold, New York
Burke, C. E., England (I. S. P.)
Burkley, Ed, Oklahoma
Burley, Fred H., Michigan
Burn, G. A. H., Canada
Burnett, A. H., Canada
Burnett, J. E., Michigan
Burnson, Blair I., California
Burr, R. S., New England
Burrell, Robert, New England
Burrin, Thomas J., Central States
Burt, G. L., Central States
Bush, A. F., California
Bush, Archie E., New York
Bush, Bernard S., Pennsylvania
Bush, M. M., Canada
Bush, Wesley A., Arizona
Bushee, Ralph J., Central States
Buss, Paul E., Canada
Butler, Leo M., Florida
Butrico, Frank, New York
Butterfield, C. T., Federal
Bye, Norval E., Canada
Byxbee, J. F., California

Cabana, L. P., Canada
Cadwell, Ivan W., New York
Cahaly, Fozi M., New England
Cahill, Wm. J., Jr., New York
Caird, James M., New York
Calder, Chas. L., California
Calderara, O. J., Federal
Caldwell, Chas. G., Rocky Mountain
Caldwell, David H., California
Caldwell, H. L., Central States
Calihan, Resler, Ohio
Callen, Loy A., Central States
Callon, Harry A., Central States
Calvert, A., England (I. S. P.)
Calvert, C. K., Central States
Cambridge Instrument Co., Associate, Att'n: F. G. Paully
Cameron, A. B., Michigan
Cameron, Geo., New Jersey
Cameron, W. M., England (I. S. P.)
Camp, Cecil S., North Carolina
Camp, R. H., England (I. S. P.)
Camp, Thomas R., New England
Campbell, John, Pennsylvania
Campbell, J. L., England (I. S. P.)
Campbell, M. S., Pacific Northwest
Campbell, M. S. A., Central States
Campbell, S. E., Oklahoma
Candel, E. J., California
Cannon, J. T., Canada
Capano, Sam J., New Jersey
Capen, Chas. H., Jr., New Jersey
Capone, Domenic, Federal
Capraro, Paul E., Central States
Capwell, Walter, New England
Caracausa, Albert C., New England
Cardwell, Edward C., Central States
Carelli, Anthony W., California
Carl, Chas. E., Missouri
Carlson, A. J., Canada

Carlson, H. R., Federal
Carlson, Paul R., Central States
Carmichael, David W., New Jersey
Carnahan, C. T., Federal
Carnwath, James, Canada
Carolina Aluminum Co., North Carolina
Carollo, John A., Arizona
Carothers, Chas. H., Florida
Carpenter, Carl B., Central States
Carpenter, Geo. D., New York
Carpenter, Harry C., New York
Carpenter, Harry E., New York
Carpenter, Howard F., New England
Carpenter, J. D., Pennsylvania
Carpenter, Wm. T., New York
Carruth, Frank E., New Jersey
Carson, R. G., Central States
Carter, Alton B., California
Carter, Earl, Central States
Carter, N. C., Pennsylvania
Carter, Co. Ralph B., Associate, Att'n: J. W. Van Atta
Cary, F. Arthur, New York
Cary, Glen, Rocky Mountain
Cary, W. H., Jr., Federal
Casad, C. C., Pacific Northwest
Case, Raymond G., New Jersey
Castello, Walter O., California
Caster, Arthur, Central States (Dual-Ohio)
Catlett, Geo. F., Texas
Caulwell, Wilson B., Pennsylvania
Caverly, D. S., Canada
Cederberg, C. R., Rocky Mountain
Cenicola, Samuel, New Jersey
Cerny, Paul J., New York (Dual-New England)
Chain Belt Co., Associate, Att'n: W. B. Marshall
Chairman, The Sewage Disposal Committee, England (I. S. P.)
Chalmers, A. E., Canada
Chamberlain, L. H., New York
Chamberlain, Wm. T., New York
Chamberlin, Noel S., New Jersey
Chambers, Grover, Pacific Northwest
Chamier, Albert, Michigan
Chanlett, Emil T., California
Chapman, Howard W., Federal
Chapman Valve Mfg. Co., Associate
Charlton, David B., Pacific Northwest
Chase, E. Sherman, New England (Dual-New York and Pennsylvania)
Chasick, Abraham H., New York
Chenevert, J. G., Canada
Chester, Burke, Florida
Chicago Pump Co., Associate, Att'n: Milton Spiegel
Chisholm, D. M., Canada
Chisholm, Henry, New England
Christensen, A. G., New Jersey
Christian, J. A., England (I. S. P.)
Christianson, A. C., Michigan
Christopher, J. B., Missouri
Chrysler, K. L., Montana
Chubb, Robert S., Pennsylvania
Chumard, Geary W., New York
Chumley, Robert L., Texas
Church, Dean F., Central States
Church, H. J., Canada
Chutter, W. H., California
Ciaccio, P. L., California
City Health Dept. (El Paso, Texas) Texas
City Water Dept. (Statesville, N. C.), North Carolina
Clare, H. C., Pacific Northwest
Clark, Arthur T., Central States, New York
Clark, Boyd H., New York
Clark, Clarence, Ohio
Clark, H. C., Michigan
Clark, H. W. England (I. S. E.)
Clark, John, Canada
Clark, J. C., California
Clark, Kenneth M., Central States
Clark, Lloyd K., Dakota
Clark, Robert N., New York (Dual-Federal)
Clark, Wayne, California
Clarke, Samuel M., Central States
Clarke, V. B., New England
Clarkson, G. H., Canada
Clary, Wm. R., New England
Classen, Ashley G., Texas
Clawson, Earl M., Florida
Clay, H., England (I. S. P.)
Clay Products Assoc., Associate, Att'n: J. D. Cook
Clear Lake, City of, Iowa
Cleary, Edward J., New Jersey
Cleland, R. R., Pennsylvania
Clements, G. S., England (I. S. P.)
Cleveland, E. A., Canada
Clifford, W., England (I. S. P.)
Climax Engineering Co., Associate, Att'n: E. D. West
Clinton, Merritt O., Central States
Clore, L. B., Central States
Clouser, L. H., Pennsylvania
Cloyes, W. J., Pacific Northwest
Cobb, Edwin B., New England
Coberly, Carroll H., Rocky Mountain
Cobleigh, W. H., California
Cobleigh, W. M., Montana
Coburn, S. E., New England
Cochrane, W. F., Dakota
Cochrane, John C., New York
Cockroft, T. N., England (I. S. P.)
Coffey, Michael J., New York
Coffin, Edwin F., Jr., Federal
Coffin, Geo. W., New England
Cohn, Morris M., New York (Dual-New England)
Cohrs, R. W., Canada
Colby, Wm. D., Canada
Cole, Chas. W., Central States
Cole, E. Shaw, New York
Cole, Harvey M., Jr., California
Coleman, Dwight B., New York
Collard, A. E., England (I. S. E.)
Collier, James, Ohio
Collier, J. D., Canada
Collins, A. J., England (I. S. E.)
Collins, A. Preston, California
Collins, John T., New York
Collins, Rex, Oklahoma
Collins, W. H., Canada
Collison, Lloyd S., Canada
Collison, Okla C., Missouri
Collyer, Joseph C., New York
Colquhoun, Colin, New York
Colsen, Justin, Dakota
Colvin, Dean F., Central States
Comita, Gabriel W., Central States
Compton, C. R., California
Conant, F. M., Canada
Conlon, Edward W., New York
Connell, C. H., Texas
Connell, Maurice H., Florida
Connors, F. H., Ohio
Connors, Joseph J., California
Conrad, L. C., Pennsylvania
Conrad, W. E., Ohio
Consoer, Arthur W., Central States
Cook, J. W., Jr., Missouri
Cook, John O., Arizona
Cook, Lawrence H., California
Cook, Leland, Jr., California
Cook, Max E., California
Cook, S. J., Canada
Cooley, E. C., California
Cooley, Henry A., New York
Coombs, E. P., England (I. S. E.)
Cooper, G. F., England (I. S. P.)
Cooper, G. H., England (I. S. P.)
Coope, Albert, Ohio
Copeland, Kern H., California
Copeland, Wm. R., New England (Dual-New York)
Copenhauer, Irvin D., Oklahoma
Coplen, Warren W., Rocky Mountain
Copley, Chas. H., New England
Corbett, Walter E., New England
Corcoran, J. D., Canada
Corddry, W. H., Pennsylvania
Corey, R. H., Pacific Northwest
Corless, M. T., Canada
Cornell, R. M., Central States
Cornilson, C. K., Central States
Corpstein, Oswald, Central States
Corrington, C. E., Central States
Corsat, Andrew, Florida
Corson, B. I., New Jersey
Corson, H. H., Michigan
Cortelyou, H. P., California
Cortese, J. R., Montana
Cory, J. C., Montana
Cosens, Kenneth W., Michigan
Cosman, Ernest, Canada
Cosner, Lafayette, Pennsylvania
Costello, John J., New York
Cotta, Maurice L., Pacific Northwest
Cotterell, G. T., England (I. S. E.)
Cotton, Edwin R., New York
Cottrell, H. S., New York
Couch, L. I., Central States
Coulson, C. L., Canada
Cousineau, A., Canada
Covert, H. R., Central States
Covill, R. W., England (I. S. P.)
Cowden, Burney B., Florida
Cowles, M. W., New Jersey
Cox, Alvin W., California
Cox, C. R., New York
Cox, Clifford B., Central States
Coy, Burgis, Rocky Mountain
Coyne, James J., Missouri
Craemer, Geo. H., New England
Craig, Clifford, Central States
Craig, J. D., Georgia
Cranch, Eugene T., New York
Crane Company, Associate, Att'n: G. W. Hauck
Crane Company, Arizona
Crane, Harlan B., New York
Craun, Edward P., Ohio
Craun, J. M., Ohio
Craun, R. D., Michigan
Crawford, D. E., Canada
Crawford, H. V., New York
Crawford, James H., Federal
Crawford, L. C., Iowa
Crawford, Samuel, Pennsylvania
Crawford, Sinclair S., Jr., Texas
Crawley, Geo. M., Pennsylvania
Creears, T. H., California
Crepeau, Louis, Canada
Crist, Marion L., Arkansas
Critoph, Denis, Canada
Crocker, B. A., Texas
Crocker, Harold S., New England
Crockett, Vernon P., Federal
Crohen, W. F., Ohio
Crohurst, Harry T., Federal
Crooks, Howard, Michigan
Croom, Hardy C., Florida
Cross, Russell, Central States
Crow, Harry B., Pacific Northwest
Crundall, S. F. W., England (I. S. P.)
Culley, Walter M., New York
Culli, Geo. O., Jr., Texas
Cullison, Eugene F., New York
Cunetta, Joseph, New York
Cunningham, H. L., Pennsylvania
Cunningham, John J., Arizona
Cunningham, John W., Pacific Northwest
Cunningham, M. B., Oklahoma
Currie, Frank S., California
Curtis, Clive W., Central States
Curtis, Maynard J., Ohio
Cushing, Robert, Arizona
Cushman, Sumner P., Central States
Cutting, O. S., Pacific Northwest
Cyr, Rene, Canada

D'Aleo, A. R., New York
Dahl, Arve H., Federal
Daley, Stanley J., Central States
Daly, James, A., Canada
Damerow, Harry W., Florida
Damon, Nelson A., New England
Damon, Wayne F., New England
Daniels, F. E., Pennsylvania
Daniels, Hershel, Central States
Danse, L. A., Michigan
Dappert, Anselmo F., New York
Darby, Geo. M., New England
Darby, W. A., Pennsylvania (Dual-New York)
Darling, E. H., Canada
Dashiell, Walter N., Federal
Davenport, Geo. L., Jr., Arizona
Davenport, Llewellyn D., California
Davey, H. W., California
David, Frank J., Ohio
Davids, E. M., California
Davidson, A. B., Ohio
Davidson, Geo., Georgia
Davidson, J. F., California
Davidson, John, Canada
Davis, Albert E., New Jersey
Davis, C. J., Jr., Central States
Davis, Charles A., Rocky Mountain

Davis, Clarence A., New York
Davis, D. A., Central States
Davis, Edward T., Pennsylvania
Davis, Frederick E., Central States
Davis, H. A., Central States
Davis, H. F., North Carolina
Davis, P. D., North Carolina
Dawson, Arthur, New York
Dawson, F. M., Iowa
Dawson, Norman, Central States
Dawson, Thomas T., North Carolina
Day, C. G., Pennsylvania
Dayton, Alfred E., New York
Deane, Elmer L., New England
Dearborn, S. Sherman, Canada
DeBerard, W. W., Central States
DeBrito, F. Saturnino, Jr., New York
DeBrun, John W., Jr., Central States
Decher, Edward P., New Jersey
Decker, C. D., Ohio
Decker, Walter G., Central States
Deckert, Christ, Central States
de Goicoechea, Leondro, Florida
DeGroat, Frank N., New York
DeHaai, Ira, Dakota
DeHaas, Nicholas, New England
DeHooghe, Bernard A., Michigan
Deitch, Meyer, New York
deJarnette, N. M., Georgia
Delano, E. Huntley, Michigan
Delaporte, A. W., Canada
De Laval Steam Turbine Co., Associate, Att'n: H. V. Petersen
DeLeuw, C. E., Central States
Delisle, E. A., Canada
Dellasala, John J., New York
Dellett, Elmer E., Pennsylvania
DeMartini, Frank E., California (Dual-Federal)
Demorest, S. L., Michigan
Dempsey, W. T., Canada
Dempster, Andrew T., Michigan
DeMunn, E. M., New York
Denise, Wm. D., New York
Dennelly, Philip G., New York
Dennis, Carl E., Michigan
Dent, Harry, New York
DePoy, A. G., Central States
DePriest, Chas., Ohio
Derby, Ray L., California
Dermitt, Chas. W., Pennsylvania
DesBaillets, C. J., Canada
Deslauriers, A. J., Canada
Desmarais, R. J., Canada
Des Moines, City of, Iowa
Deuchler, Walter E., Central States
Devendorf, Earl, New York
Devers, Theo. J., Central States
DeVore, Ralph, Oklahoma
DeWante, Randolph H., California
Dewart, Donald M., New York
deZevallos, B. Fernando Ortiz, Florida
Dick, Chas., Canada
Dick, Robert, Jr., Central States
Dickey, Clay Mfg. Co., W. S., Associate, Att'n: A. G. Frerking
Dickson, Harvey J., Michigan
Diefendorf, Fred G., Pennsylvania
Dietz, Irving M., Texas
Dietz, J. C., Central States
DiIorio, Anthony F., New Jersey
Diller, Walter W., Central States
Dimmitt, Bruce S., Central States
Dion, Clarence K., New England
Disario, G. M., New England
Disher, D. M., Canada
Dixon, F. S., Dakota
Dixon, G. Dale, New York
Dixon, R. M., Texas
Dobson, Wm. T., New York
Dobstaff, R. W., Sr., New York
Dobstaff, Robert, Jr., New York
Dodd, C. K. S., Florida
Dodge, H. P., Michigan
Doggett, Wm. H., New England
Doman, Joseph, New England (Dual-New York)
Domke, L. C., Central States
Domlesky, Leonard A., Pennsylvania
Domogalla, Bernard, Central States
Donaldson, Wellington, New York
Donnell, Geo. M., Rocky Mountain
Donnelly, R. M., New England
Donnini, Frank L., New England
Dopmeyer, Arthur L., California (Dual-Federal)
Dore, Stanley M., New England
Dornbush, Donald, Michigan
Dorr Co., Inc., Associate
Dorr, Fred M., Michigan
Douglas, Geo. F., Pacific Northwest
Douglass, R. M., Pennsylvania
Dow Chemical Co., Associate, Att'n: W. A. Melching
Downer, Wm. J., Central States
Downes, John R., New Jersey
Downing, Francis J., New York
Doyle, Thomas J., Michigan
Doyle, Wm. H., Central States
Drake, James A., Central States
Dreier, Douglas E., Central States
Drew, Samuel T., New England
Drexel, Frederick, New York
Driscoll, Timothy J., New York
Drummond, A. H., England (I. S. P.)
Drummond, C. E., Georgia
DuBois, F. W., Michigan
Dudley, D. E., Central States
Dudley, Richard E., New England
Duell, Garth H., California
Dufficy, Frank J., New York
Duffy, Ora, Kansas
Dufresne, Paul E., Canada
Duncan, J. G., Canada
Duncan, Stratton & Co., Ltd., England (I. S. P.)
Dundas, Wm. A., Central States
Dunger, Henry A., Missouri
Dunmire, E. H., Central States
Dunn, James W., New Jersey
Dunn, Leslie, Ohio
Dunseth, R., Central States
Dunstan, Gilbert H., California
DuPont, Anthony W., New England
Durand, Edwin M., Michigan
Durham Water Dept., (North Carolina), North Carolina
Durr, John J., Jr., Pennsylvania
Durrant, W. K. F., Canada
Dust, J. V., Central States
Duvall, Arndt J., Central States
Dworsky, L. B., Central States
Dyckman, Warren W., New York
Dyer, Samuel, New England
Dyrenforth, Donald, Rocky Mountain
Dyson, R. J. H., England (I. S. P.)

Eager, Vernon, New York
Eagleson, John W., New York
Early, Fred J., Jr., California
Early, Mart, Pacific Northwest
Easdale, W. C., England (I. S. E.)
Easley, G. E., California
Eastburn, Wm. H., New York
Easter, Chas. W., New England
Easter, Leonard C., New England
Easthagen, J. H., California
Eaton, Thomas J., Pennsylvania
Eberle Tanning Co., (Corporate), Pennsylvania
Ebneter, Walter, Central States
Eby, Earl, Montana
Eckbert, Chester A., Pennsylvania
Eckelcamp, Joseph, Michigan
Ecusta Paper Corp., North Carolina
Eddy, Harrison P., Jr., New England
Edgecombe, G. H., Canada
Edgerley, Edward, Pennsylvania
Edighoffer, Albert, New York
Edinger, Harry F., New York
Edis, Wm. H., California
Edmonds, W. R., Canada
Edmondson, E. B., Texas
Edmondson, J. H., England (I. S. P.)
Edwards, Clement, Canada
Edwards, G. H., Pacific Northwest
Edwards, Gail P., New York
Edwards, J. Eastman., Ohio
Edwards, Myles W., Pennsylvania
Edwards, Stacy W., Texas
Edwards, Wm. L., New York
Egan, J. H., California
Egger, Oscar O., Central States
Eglof, Warren K., New York
Ehle, Virgil, New York
Eich, Henry F., New York
Eidsness, Fred A., Georgia
Eiffert, Wm. T., Pacific Northwest
Eimco Corporation, Associate, Att'n: Paul O. Richter
Einsele, Robert, Central States
Elder, Leiton J., California
Eldridge, E. F., Michigan
Electro Rust-Proofing Co., Associate, Att'n: E. H. Ingle
Elias, Geo. A., Pennsylvania
Eliassen, Rolf, New York
Elkland Leather Co., Inc., (Corporate), Pennsylvania
Ell, Henry T., New Jersey
Ellerbusch, R. P., Michigan
Ellms, J. W., Ohio
Elmendorf, C. E., New York
Ely, E. H., England (I. S. E.)
Emerson, C. A., (Honorary) Pennsylvania
Emigh, Wm. C., Pennsylvania
Engineering News-Record, Associate
English, J. A., North Carolina
English, Joseph, Jr., Pennsylvania
English, Leslie B., Canada
Enloe, V. P., Georgia
Enslow, L. H., New York
Epler, J. E., Central States
Erganian, Geo., Central States
Erickson, Carl V., Central States
Erickson, Frederick K., Federal
Erickson, John E., Iowa
Erwin, R. Blake, Canada
Escritt, L. B., England (I. S. P.)
Espinosa-Parga, Roberto, Florida
Estabrook, Joseph B., Central States
Esterline, Harry, Ohio
Estrada, Alfred A., Pennsylvania
Ettinger, M. B., Federal
Eustance, Arthur W., New York
Eustance, Harry W., New York
Evans, Byron B., New York
Evans, David A., Pennsylvania
Evans, David C., Pennsylvania
Evans, F. M., New Jersey
Evans, James, Pennsylvania
Evans, R. W., Central States
Evans, S. C. England (I. S. P.)
Everest, Howard, New York
Everson Manufacturing Co., Associate, Att'n: R. B. Everson
Everson, R. B., Central States
Everts, Curtis M., Jr., Pacific Northwest
Extrum, C. W., Central States
Eyer, C. W., Montana

Faber, Harry A., New York (Dual-Pennsylvania)
Faehrman, Elmer H., Central States
Faget, Walter H., Central States
Fah, C. T., England (I. S. E.)
Fair, Gordon M., New England (Dual-New York)
Fairbanks, Morse & Co., Associate, Att'n: Chas. J. Prestler
Falbey, John W., Florida
Fales, Almon L., New England
Falk, Lloyd L., New Jersey
Fallon, Raymond D., Rocky Mountain
Falls, O. M., Canada
Faris, Cecil R., California
Farmer, Edward, Kansas
Farnsworth, G. L., Jr., Central States
Farrant, James, New Jersey
Farrell, Wm. F., New York
Fassnacht, Geo. G., Central States
Faulkner, T. G., England (I. S. E.)
Fawls, J. F., New York
Federick, Joseph C., New York
Fehn, Clyde F., Federal
Feild, James W., Maryland-Delaware
Feldhake, Clarence J., Federal
Feltz, Fred C., Central States
Fenchel, Randolph, California
Fenger, J. W., New York
Fenn, Ernest G., New England
Fenton, John V., New York
Ferebee, James L., Central States
Ferguson, G. H., Canada
Ferguson, Gerald W., Federal
Ferguson, Marshall E., New York
Ferris, Frederick, Pennsylvania
Ferris, James E., New England (Dual-New York)
Field, Emerson & Morgan, Inc., New York

Fieldhouse, Geo. E., Pennsylvania
Figeley, Paul, Central States
Filby, E. L., Missouri
Finch, J., England (I. S. P.)
Finck, G. E., Maryland-Delaware
Findlay, Arthur, New York
Finkbeiner, Carlton S., Ohio
Finley, T. R., Florida
Firth, Wm. J., New York
Fischer, Anthony J., New York
Fischer, F. P., Ohio
Fischer, Math., Central States
Fiscus, A. E., California
Fish, Raymond S., California
Fishbeck, Kenneth, Michigan
Fishburn, Addison S., Pennsylvania
Fisher, Lawrence M., Federal
Fisher Research Lab., Arizona
Fisk, Chas. A., Florida
Fitch, T. A., California
Fittro, Louis L., Federal
Fitzgerald, Edward P., Central States
Fitzgerald, J. A., New York
Fitzgerald, Joseph, New England
Five, Helge, New York
Fiveash, Chas. E., Florida
Flanagan, Pat, Florida
Flannery, Harold J., California
Flattery, M., Canada
Fleet, Gerald A., New York
Fleming, M. C., Pennsylvania
Fleming, Paul V., New England
Fletcher, W. J., Canada
Flexible Sewer-Rod Equip. Co., Associate, Att'n: Peter L. Ciacco
Fling, J. A., New York
Flood, Frank L., New England
Flood, T. S., Pacific Northwest
Flook, S. E., Canada
Flower, G. E., Ohio
Flowers, E., England (I. S. P.)
Fodor, P. A., Ohio
Foley, John M., New York
Fontenelli, Louis, New Jersey
Foote, H. B., Montana
Foote, Kenneth E., New England
Fore, Clifford, Central States
Foreman, Merle S., California
Forrest, Glen L., New York
Forrest, Thomas H., Central States
Forsberg, Helge, Canada
Forsyth, Joseph R., Pennsylvania
Fort Dodge, City of, Iowa
Fortenbaugh, J. Warren, New York
Fortman, John A., Central States
Forton, R. Gerald, Michigan
Foster, Chas., Central States
Foster, Herbert B., Jr., California
Foster, James R., New York
Foster, Norman, Pennsylvania
Foster, Robert F., Rocky Mountain
Foster, Wm. Floyd, California
Foster, Wm. S., New Jersey
Foth, Herbert S., Central States
Fowler, G. J., England (I. S. P.)
Fowler, H. D., Pacific Northwest
Fowler, James D., Texas
Foxboro Company, Associate
Francis, Geo. W., Michigan
Frankish, T. A., Canada
Franklin Tanning Co., (Corporate), Pennsylvania
Franks, John T., Rocky Mountain
Fraschina, Keeno, California
Fraser, Chas. E., Canada
Fraser, J. S., Canada
Frasher, Randall L., New York
Fraters, E. W., California
Frazier, Leonard H., New York
Frazier, R. W., Central States
Frazier, W. H., Central States
Frederickson, A. Anton, Arizona
Freeborn, W. F., England (I. S. P.)
Freeburn, H. M., Pennsylvania
Freeland, B. H., Central States
Freeman, A. B., Federal
Freeman, A. L., England (I. S. P.)
Freeman, L. H., Central States
Freeman, W. B., Rocky Mountain
Freer, Paul H., California
Frei, John K., Missouri
French, R. Del., Canada
Freund, J. P., Pennsylvania
Frick, A. L., Jr., California
Frick, Irvin, Ohio
Frickstad, Walter N., California
Friel, F. S., Pennsylvania
Friendly, Hugo H., New York
Frith, Gilbert R., Georgia
Froehde, F. C., California
Frost, D. P., Canada
Fuchs, Abraham W., Federal
Fuehrer, Carl W., Pennsylvania
Fugate, G. L., Texas
Fuhrman, Ralph E., Maryland-Delaware (Dual-Federal)
Fuller, Andrew J., New York
Fuller, N. M., New York
Fuller, Raymond H., Ohio
Fulmer, Frank E., Central States
Fulmer, John O., Jr., Pennsylvania
Funk, E. G., Ohio
Funk, John B., Maryland-Delaware
Funk, John T., Jr., Pennsylvania
Furphy, H. G., England (I. S. P.)
Fynn, Geo. F., New York

Gade, A. H., New York
Gadomski, Albert J., New Jersey
Gahr, Wm. N., Dakota
Gail, A. L., Central States
Gale Oil Separator Co., Associate, Att'n: Wm. A. Gehle
Galimbert, G. M., Canada
Galloway, Frank R., California
Galloway, Robert N., California
Gammon, W. S., Canada
Gard, Chas. M., New York
Gardner, Clarke, Maryland-Delaware
Gardner, R. T., California
Garland, C. F., Florida
Garner, J. H., England (I. S. P.)
Garrett, Geo. B., Jr., New England
Garrett, R. W., Canada
Garthe, E. C., Federal
Garwood, Kirk, Iowa
Gass, Geo. M., Canada
Gass, S. H., Rocky Mountain
Gatley, H. K., New Jersey
Gaus, Gilbert H., New York
Gauthier, C. W., Canada
Gavan, Wm. J., Michigan
Gavett, Weston, New York
Gearhart, J. N., Pacific Northwest
Gearhart, John C., Pacific Northwest
Gelbke, Arthur W., New York
Gelston, W. R., Central States
General Chemical Co., Associate, Att'n: L. I. Birdsall
General Electric Co., Associate, Att'n: H. V. Crawford
General Manager, Sewage Dept., (Glasgow, Scotland), England (I. S. P.)
Genter, Albert L., Maryland-Delaware
Gentlemen, Laurence M., New England
Gentsch, Edward, Michigan
George, J. B., Missouri
George, J. E., Missouri
Gerard, F. A., Central States
Gerdel, Walter E., Ohio
Gere, Wm. S., New York
Gerhart, Edgar, Pennsylvania
Gerlitz, F. E., Pennsylvania
Getz, Murray A., Central States (Dual-Federal)
Geupel, Louis A., Central States
Geyer, John C., Maryland-Delaware
Gibbons, E. V., Canada
Gibbons, M. M., New Jersey
Gibbs, Frederick S., New England
Gibeau, H. A., Canada
Gibson, W. B., Georgia
Gibson, Wm. J., New York
Gidley, H. K., Pennsylvania
Giesey, J. K., Central States
Gifford, J. B., Central States
Gifft, H. M., New York
Gilbert, J. J., Pennsylvania
Gilbert, J. Miles, Florida
Gilbertson, Wesley E., Federal
Gilchrist, Tom, Canada
Gilcreas, F. Wellington, New England (Dual-New York)
Gilcrest, R. V., Kansas
Giles, J. Henry L., New England
Gilfrey, Grant S., Rocky Mountain
Gill, Harry J., California
Gill, John B., California
Gill, Paul, Pennsylvania
Gillard, J. E., England (I. S. P.)
Gillelen, Frank, California
Gillespie, C. G., California
Gillespie, Edward, Texas
Gillespie, Wylie W., Florida
Gillett, S. Howard, Canada
Gilman, Floyd, New York
Gilman, N. A., Pacific Northwest
Girand, John, Arizona
Girard, Francis R., New England
Gisborne, Frank R., New England
Gittins, John W., Pennsylvania
Glace, I. M., Pennsylvania (Dual-New York)
Glace, I. M., Jr., Pennsylvania
Gladding, Chas., California
Glamorgan Pipe & Foundry Co., Associate
Glasser, Leo M., New York
Glines, Robert A., New England
Gmeiner, Frank, Central States
Godfroy, J. I., Michigan
Godshall, Horace E., Pennsylvania
Goebelle, Norman J., Canada
Goeke, Roscoe H., Federal
Goff, James S., New England
Goff, Wm. A., Pennsylvania
Gohde, Chas. H., Central States
Goldsmith, Philip, New York
Goldthorpe, H. H., England (I. S. P.)
Golly, M. R., Central States
Gooch, E. W., Pacific Northwest
Goodman, Arnold H., Central States
Goodnight, V. L., Pacific Northwest
Goodridge, Harry E., California
Goodwin, S. E., Canada
Gordon, Arthur, Central States
Gordon, Chas. W., Central States
Gorman, A. E., Federal
Gorman, Richard C., Jr., New York
Gorman, Wm. A., Pennsylvania
Gotaas, Harold B., North Carolina
Gothard, N. J., Central States
Goudey, R. F., California
Gould, Richard H., New York
Grabbe Construction Co., H. A., Central States
Grabbert, Gilsey R., Central States
Graber, Ralph C., Federal
Grabowski, John J., Pennsylvania
Gracenin, Sylvester, Pennsylvania
Graemiger, Joseph A., New England
Graham, E. H., California
Graham, Edward J., New York
Graham, James E., Michigan
Graham, Maynard, Rocky Mountain
Graham, Wm., California
Gran, John E., Georgia
Granger, Geo. M., New England
Grant, Howard L., Texas
Grantham, G. R., Central States
Graul, Leroy H., New Jersey
Graves, Quintin B., Dakota
Graves, Wallace M., New Jersey
Gray, Earl G., Michigan
Gray, Harold F., California
Gray, Wm., Canada
Greeley, Richard F., New England
Greeley, Samuel A., Central States
Green, Alvin W., Pacific Northwest
Green Bay Fdy & Machine Wks., Associate, Att'n: James P. North
Green, Carl E., Pacific Northwest
Green, Howard R., Iowa
Green, Richard S., Federal
Green, Roy F., Central States
Green, Thomas C., Texas
Green, Wingate, Florida
Greene, R. A., Michigan
Greenfield, H. C., New Jersey
Greenleaf, John W., Jr., New England
Gregory, The John H. Sanitary & Municipal Reference Library, California
Gregory, Ted R., California
Greiff, Victor C., New York
Greig, John M. M., New York
Gregory, Tom, Central States
Grelick, David, New York
Griffin, A. E., New Jersey
Griffin, D. P., Ohio
Griffin, F. T., New York
Griffin, Guy E., New England
Griffith, Chas. R., Central States
Grimes, Ben L., Jr., Texas

Grimm, R. L., Missouri
Grimmer, A. K., Canada
Grimsley, J. T., Federal
Grinnell Company, Inc., The, North Carolina
Griswold, Harold S., Central States
Groen, Michael A., Michigan
Gronberg, W. E., Central States
Groseclose, Herman, Oklahoma
Gross, Carl D., Central States
Gross, Dwight D., Rocky Mountain
Gross, Fred W., Jr., New York
Grossart, L. J. H., Pennsylvania
Grosshans, Edward W., Central States
Grover, Robert H., New York
Growden, H. C., Ohio
Gruendler Crusher & Pulverizer Co., Associate, Att'n: Wm. P. Gruendler
Gruss, A. W., California
Gruss, John G., Pennsylvania
Guernsey & Co., C. H., Oklahoma
Guinn, Frank, Ohio
Gulden, Horace B., Pennsylvania
Gunther, G. A., Central States
Gurton, Wm. S., Canada
Guthrie, Perry, Ohio
Guy, L. E., Ohio
Gwin, Lewis L., Pennsylvania
Gwin, Thomas M., California
Gyatt, W. P., New York

Haag, Gerald, Central States
Habermehl, C. Austin, Michigan
Hackett, Peter, New York
Haddock, Fred R., Pennsylvania
Hadley, Henry, Canada
Haemmerlein, Victor E., New York
Hagar, C., Kansas
Hager, Everett C., California
Hager, Fred, Central States
Hager, J. Wm., California
Hagerty, L. T., Ohio
Hagey, C. R., Canada
Haimes, James, Canada
Haiss, Carl E., New York
Hakim, Bahij Al, Central States
Hale, Arnold H., New York
Hale, Elliott J., New England
Hale, Harry C., Missouri
Halff, Albert H., Central States
Hall, Frank H., New York
Hall, G. D., Pacific Northwest
Hall, Geo. A., Ohio (Dual-Pennsylvania)
Hall, Geo. L., Central States
Hall, Geo. M., Central States
Hall, Harry R., Maryland-Delaware
Hall, John W., Montana
Hall, S. P., Central States
Hall, W. H., North Carolina
Hall, W. N., Canada
Hallam, G. C., Pacific Northwest
Hallgren, R. A., Canada
Halpin, John, New York
Halvorson, H. O., Central States
Hambleton, F. T., England (I. S. P.)
Hamilton, G. M., Canada
Hamilton, H. L., Canada
Hamilton, L. A., Central States
Hamilton, R. C., Central States
Hamilton, R. F., Pacific Northwest
Hamm, Wm. C., New York
Hammann, Chas. G., New England
Hammerstrom, Richard J., Federal
Hammond Bd. of Sanitary Commissioners, (Corporate), Central States
Hammond, Geo. R., Pacific Northwest
Hammond, Harry P., Pennsylvania
Hammond, Robert H., California
Hammond, Vergil, Central States
Hanes, Gilbert C., California
Haney, Paul D., Kansas
Hankin & Co., Ltd., Francis, Canada
Hanlon, D. A., Florida
Hanlon, Joseph B., New England
Hansell, Wm. A., Jr., Georgia
Hansen, Alfred E., Michigan
Hansen, Carl, California
Hansen, Chris A., Federal
Hansen, Herbert W., Ohio
Hansford, A. E., Canada
Hanson, Arthur C., Central States
Hanson, Arthur M., New England
Hanson, Geo. I., New England
Hanson, Harry G., Dakota (Dual-Federal)
Hapgood, E. P., California
Hardcastle, R. C., Oklahoma
Hardenbergh, W. A., New York
Hardenburgh, E. A., California
Harding, Elwood R., Pennsylvania
Harding, James C., New York
Harding, Robert G., Pacific Northwest
Hardinge Company, Associate, Att'n: M. C. Fleming
Hardman, Thomas T., Central States
Hardy, C. Asa, New York
Hardy, Wm. G., New England
Hargleroad, James C., Central States
Hargraves, Z. D., Michigan
Harlamert, P. A., Ohio
Harley, Frank E., New Jersey
Harmeson, Donald J., Central States
Harmon, Jacob A., Central States
Harmon, Judson A., California
Harper, Travis C., California
Harr, Neal, Kansas
Harris, Geo. C., Central States
Harris, H. E., Florida
Harris, I., England (I. S. P.)
Harris, J. F., Pennsylvania
Harris, Roy M., Pacific Northwest
Harris, T. R., Central States
Harris, Thomas, New York
Harrison, Cecil, Oklahoma
Harrison, Edward F., New York
Harrison, John B., California
Harrison, Louis B., Michigan
Harrison, Robert L., Ohio
Hart, S. J., Missouri
Hart, W. B., Pennsylvania
Harte, John J., Georgia
Hartley, John J., New England
Hartley, John R., New England
Hartman, B. J., Central States
Hartung, N. E., Central States
Harvey, Carl, New York
Harvey, Chester, Michigan
Harvey, J. B., England (I. S. P.)
Harvey, J. R., Pennsylvania
Harwell, G. A., Missouri
Haseltine, T. R., Pennsylvania
Hasfurther, Wm. A., Central States
Haskins, Chas. A., Missouri
Haslett, R. N., Jr., Georgia
Hastie, James, New York
Hastings, W. E., New York
Hatfield, W. D., Central States
Hattery, Chas. E., Central States
Hauck, Chas. F., Ohio
Hauer, Gerald E., Michigan
Haven, John F., Pennsylvania
Havens, Wm. L., Ohio
Haworth, J. V., Pennsylvania
Haworth, W. D., England (I. S. E.)
Hawtrey, R. O., Canada
Hay, T. T., Central States
Hayden, John L., New England
Haydock, Chas., Pennsylvania
Hayes, John A., New York
Hayob, Henry, Jr., Missouri
Hays, Clyde C., Texas
Hayward, Homer J., Michigan
Haywood, R. W., Jr., Pennsylvania
Hazen, John B., Montana
Hazen, Richard, New York
Hazey, Geo., Michigan
Heath, J. Ray, Pacific Northwest
Heckman, Fred, Missouri
Heckman, L. M., Kansas
Hedenstad, Paul C., New England
Hedgepeth, L. L., Pennsylvania (Dual-New York)
Heffelfinger, D. D., Ohio
Heider, Robert W., Central States
Heim, Mitzi S., Central States
Heinrikson, J. J., Kansas
Heinz, J. Ralph, Pennsylvania
Heiple, Loren R., Central States
Heisig, H. M., Central States
Heiss, Edward A., Pacific Northwest
Heister, R. M., Pennsylvania
Helgeson, Andrew, Dakota
Helland, H. R. F., Texas
Heller, Austin N., New York
Heller, C. F., Pennsylvania
Heller, Lloyd J., Central States
Helwick, Chas. T., Florida
Henderson, J. E., England (I. S. P.)
Henderson, Paul C., Federal
Hendon, H. H., New York
Hendricks, Gerald F., Central States
Henley, M. E., Georgia
Henn, Donald E., Central States
Hennigan, John J., New Jersey
Henny, A. L., Pacific Northwest
Henry, Forrest R., Pennsylvania
Henry, Thomas B., Ohio
Hensel, Eugene C., Central States
Herberger, Arthur Henry, New York
Herda, N., Michigan
Herman, F. X., Central States
Herr, H. N., Pennsylvania
Herrick, T. L., Central States
Hersey Manufacturing Co., Associate, Att'n: Wm. C. Sherwood
Herzig, S. B., Central States
Herzog, Henry, New York
Hesenpfling, Geo., Ohio
Hesford, L., England (I. S. E)
Hess, Daniel J., Jr., Pennsylvania
Hess, Edward C., Pennsylvania
Hess, John S., Ohio
Hess, Seth G., New York
Heubi, Thomas, New York
Heukelekian, H., New Jersey
Hewitt, A. C., Pennsylvania
Heyward, T. C., North Carolina
Hibbs, Edwin B., Texas
Hibschman, Chas. A., Pennsylvania
Hicklin, R. G., Georgia
Hicks, Cyril, Michigan
Hicks, R., England (I. S. P.)
Hicks, R. H., Maryland-Delaware
Higgins, Geo. F., Florida
Higgins, James A., Pacific Northwest
Higgins, Thomas E., Jr., New York
Higgins, Wm. J., New York
Hilbert, Morton S., Michigan
Hill, G. Everett, New York
Hill, John R. S., Federal
Hill, K. V., Central States and California
Hill, R. N., England (I. S. P.)
Hill, Theodore C., Pennsylvania
Hill, W. R., Pacific Northwest
Hiller, Paul W., New England (Dual-New York)
Hillier, W. H., England (I. S. P.)
Hillis, Leonard, Michigan
Hillsboro, Town of, (Hillsboro, N. C.), North Carolina
Hilton, Elton M., California
Hinkamp, Grant M., (Corporate), Central States
Hinmon, Don, California
Hintgen, Geo. W., Federal
Hipple, James F., Pennsylvania
Hirn, Wm. C., Michigan
Hirtler, Wm., California
Hiskey, D. R., California
Hitchner, A. H., California
Hitchcock, S. E., Canada
Hoak, Richard D., Pennsylvania
Hobson, Edward, Pacific Northwest
Hodge, W. W., Pennsylvania
Hodges, H. E. W., England (I. S. E.)
Hodgkinson, Jack, California
Hodgson, E., England (I. S. P.)
Hodgson, H. J. N., England (I. S. P.)
Hodkinson, C. T., Central States
Hoeflich, G. C., Pennsylvania
Hoey, A. C., Canada
Hoffert, J. R., Pennsylvania
Hoffman, C. H., Pacific Northwest
Hoffman, Howard F., New York
Hogan, James W. T., New York
Hogan, M. S., Missouri
Hogan, Wm. J., New York
Hoganson, Lester O., Central States
Holborn, C. J., Dakota
Holcomb, Howard B., New York
Holden, Adolph, Missouri
Holderby, J. M., Central States
Holderman, John S., Central States
Holland, Frank H., New York
Hollins, C. D., Central States
Hollis, M. D., Federal
Holloway, E. L., Michigan
Holman, Albert L., Federal
Holmes, Glenn D., New York
Holmes, Harry E., New England
Holmes, Kenneth H., New England
Holmquist, Chas. A., New York

Holroyd, A., England (I. S. P.)
Holroyd, Norman S., New York
Holst, J. E., Dakota
Holt, Clayton M., Central States
Holter, A. L., Pacific Northwest
Holtje, Ralph H., New Jersey
Holy, Wm. E., Federal
Homan, Arthur R., Missouri
Homelite Corporation, Associate, Att'n: Nelson Thompson
Hommon, Chas. C., Ohio
Hommon, H. B., California
Hood, John W., New Jersey
Hoot, Ralph A., Central States
Hoover, C. B., Ohio
Hope, Malcolm C., Federal
Hopkins, Edward S., Maryland-Delaware
Hopkins, Glen J., Federal
Hopkins, L. S. R., New York
Hopkins, Omar C., Federal
Hopper, Allen O., New York
Horgan, John J., New York (Dual-New England)
Horn, A. John, New York (Dual-Pennsylvania)
Horne, Ralph W., New England
Horner, Geo. I., Canada
Horner, J. L., Texas
Horner & Shifrin, Missouri
Hoskins, J. K., Federal
Hoskinson, Carl M., California
Hoss, James, Missouri
Hotchkiss, H. T., Jr., New York
Hoth, Fred, Central States
Houser, Geo. C., New England
Houser, Wm. E., Ohio
Houston, J. W., Georgia
Howard, C. M., Pacific Northwest
Howard, Earl R., New England
Howard, N. J., Canada
Howard, Paul F., New England
Howard, R. R., Missouri
Howarth, J. P., England (I. S. P.)
Howe, Ben V., Rocky Mountain
Howe, J. P., Canada
Howe, Martin W., Canada
Howell, Eugene M., California
Howland, W. E., Central States
Howson, J. T., New York
Howson, L. R., Central States
Hoy, J. R., Florida
Hoyle, W. H., England (I. S. P.)
Hoyt, Clinton W., New York
Hoyt, Earle S., Ohio
Hromada, Frank M., Central States
Hu, Chin Tsun, New England
Hubel, J. H., Canada
Hubbell, Geo. E., Michigan
Hubeny, Karl, Pennsylvania
Huber, Harold J., New York
Hudson, John P., Canada
Hudson, L. D., Central States
Huether, A. D., Canada
Huebner, Ludwig, California
Huffman, Fred, California
Huffman, Lloyd C., Ohio
Hufford, L. E., Ohio
Hughes, V. R., Oklahoma
Hughes, W. P., Pacific Northwest
Hulse, C. A., Canada
Hume, Norman B., California
Humphreys, G. Howard, England (I. S. E.)
Hunt, Henry J., Central States
Hunt, H. S., Michigan
Hunt, L. W., Central States
Hunt, Wm. J., Jr., New York
Hunter, Colus C., New York
Huntress, C. O., Missouri
Hupp, John E., Jr., Central States
Hurd, Chas. H., Central States
Hurley, J., England (I. S. P.)
Hurst, Chas., Central States
Hurst, D. H., Georgia
Hurst, W. D., Canada
Hurtado, J. R., Florida
Hurwitz, Emanuel, Central States
Hussong, Ernest W., Central States
Hutchins, Will A., Central States
Huth, Norman A., California
Hutton, H. S., Pennsylvania
Hyatt, Carl, Rocky Mountain
Hyde, Chas. Gilman (Honorary) California
Hyde, Frank E., Georgia
Hyland, Wm. L., New England

Iantosca, Angelo, New England
Ignacio, Krouse A., Federal
Illinois Dept. of Public Health, (Corporate), Central States
Imbt, M. Russell, Pennsylvania
Indiana State Bd. of Health, Att'n: B. A. Poole, (Corporate), Central States
Infilco, Inc., Associate, Att'n: H. W. Gillard, (Corporate), Central States
Ingols, Robert S., Michigan
Ingram, Wm. T., California
Iowa City, City of, (Iowa), Iowa
Iowa Falls, City of, (Iowa), Iowa
Iowa Valve Co., Associate, Att'n: J. W. Dousette
Irvine, A. S., Canada
Irwin, G. M., Pacific Northwest
Iscol, Geo., New York

Jablon, Fred M., New York
Jack, David, Canada
Jack, Grant R., Canada
Jackson, R. B., Michigan
Jackson, S., England (I. S. P.)
Jacobs, J. R., Georgia
Jacobs, W. H., Ohio
Jacocks, F. A., Federal
Jacquart, Matt, Dakota
Jaffe, Theodore, Pennsylvania
James, Chas., Ohio
James, Glenn, Central States
James, Norman S., Florida
Janzen, Herman A., Kansas
Jarlinski, Alice M., New York
Jarlinski, Thaddeus T., New York
Jarvis, Alec. C., England (I. S. P.)
Jasper, Galen J., (Corporate), Central States
Jeffrey, H. H., California
Jeffrey Manufacturing Co., Associate, Att'n: S. L. Tolman
Jenckes, J. Franklin, Jr., New England
Jenkins, Joe E., Texas
Jenks, Glen, Rocky Mountain
Jenks, Harry N., California
Jenne, Lyle L., Pennsylvania
Jenner, Geo. L., Missouri
Jennings, A., England (I. S. P.)
Jennings, J. C., California
Jennings, L. R., Michigan
Jensen, Emil C., Pacific Northwest
Jepson, C., England (I. S. P.)
Jerge, Ray, New York
Jerman Daniel L., New York
Jessup, A. H., California
Jeup, Bernard H., Central States
Jewell, H. W., California
Jewells, Geo. H., Central States
Johannessen, Walter, Arizona
John, Robert L., Pennsylvania
Johns, Alex W., Pennsylvania
Johns-Manville Corp., Associate, Att'n: R. F. Orth
Johnson, A. Stanford, Central States
Johnson, Arthur N., Central States
Johnson, C. Frank, New England
Johnson, Clement, New York
Johnson, Cleo V., Texas
Johnson, Dennis C., Central States
Johnson, E. W., Canada
Johnson, Earle P., Pennsylvania
Johnson, Floyd E., Central States
Johnson, Hamilton K., Pacific Northwest
Johnson, Henry, Central States
Johnson, Herbert O., New York
Johnson, Jess B., Central States
Johnson, John W., New York
Johnson, Kenneth R., Dakota
Johnson, L. M., Central States
Johnson, Paul B., Federal
Johnson, Robert T., Iowa
Johnson, Russell K., New York
Johnson, T. E., Pacific Northwest
Johnson, Verner C., California
Johnson, W. W., Central States
Johnson, Warren A., Missouri
Johnston, David J., Central States
Johnston, Floyd, Texas
Johnston, G. C. S., Canada
Johnstone, Alan, New York
Joiner, W. N., Texas
Jollie, Walter H., Central States
Jonas, Milton R., Central States
Jones, C. B. O., England (I. S. P.)
Jones, Daniel, New York
Jones, E. M., Pennsylvania
Jones, F. Wayland, California
Jones, Frank O, Central States
Jones, Frank Woodbury, Ohio (Dual-Pennsylvania)
Jones, Harvey P., Ohio
Jones, Ralph W., Pennsylvania
Jones, Robert J., New England
Jones, S. Leary, Federal
Jones, T. A., Georgia
Jordan, Edward C., New England
Jordan, Harry E., New York
Jorgensen, Homer W., California
Josam Manufacturing Co., Associate, Att'n: Leo N. Newman
Joy, C. Fred, Jr., New England
Junge, Gilbert H., Dakota

Kaar, G. C., Central States
Kadinger, Fred, Central States
Kachelhoffer, Fred G., Pacific Northwest
Kachorsky, M. S., New Jersey
Kafka, John, Central States
Kaiser, C. T., Ohio
Kaiser, Marvin M., New York
Kaler, P. E., Kansas
Kaltenbach, Albert B., Maryland-Delaware
Kamerling, Lane, Michigan
Kamp, Ewald A., Central States
Kane, R. D., Ohio
Kaplan, Bernard, New Jersey
Kaplan, Hilton C., Central States
Kaplovsky, A. J., New York
Kappe, S. E., Pennsylvania (Dual-New England and New York)
Karalekas, Peter C., New England
Kass, Nathan I., New York
Kay, Lawrence A., Canada
Kearney, John J., Central States
Kearney, Thomas F., Pennsylvania
Keefer, Clarence E., Maryland-Delaware
Keefer, R. K., Pennsylvania
Keehan, Daniel B., New York
Keeler, J. Harold, New York
Keeler, Russell B., California
Kehr, Wm. Q., Missouri
Keirn, Kenneth A., California
Keis, F. J., New York
Keith, J. Clark, Canada
Kelleher, Joseph A., New York
Keller, Earl D., Ohio
Keller, J., Central States
Keller, L. M., New York
Keller, S. K., Florida
Kellogg, James W., North Carolina
Kelly, Clarence, New York
Kelly, Earl M., California
Kemp, Harold A., New York (Dual-Federal)
Kempkey, A., California
Kendrick, Edward J., New York
Kenerson, Waldo I., New England
Kennedy, C. C., California
Kennedy, D. R., California
Kennedy, J. L., Rocky Mountain
Kennedy, R. R., California
Kennedy, Wm., New York
Kenney, Norman D., Maryland-Delaware
Kennison, Karl R., New England
Kepner, Dana E., Rocky Mountain
Ker, M. F., Canada
Kershaw, Arnold, England (I. S. P.)
Kessener, H., England (I. S. P.)
Kessler, Lewis H., Central States
Ketcham, Joseph M., New York
Kewer, J. F., Sr., Central States
Keyes, Harmon E., Arizona
Kibler, Harry J., New York
Kidd, Carl W., New York
Kieffer, Joseph D., New York
Kielkopf, Frederick J., Pennsylvania
Kiely, John F., New Jersey
Kiker, John E., Jr., New York
Kilborn, R. Kenneth, Canada
Kilcawley, Edward J., New York
Killam, E. T., New Jersey
Killeen, Robert F., Michigan

Kimball, Jack H., California
Kin, Stephen R., North Carolina (Dual-New York)
Kinderman, Wm., Pennsylvania
King, Arch L., Texas
King, Arthur F., Ohio
King, Ed E., Arizona
King, Henry R., Central States
King, L. H., Florida
King, L. P., California
King, Leslie R., Rocky Mountain
King, Richard, Central States
King, Wm., Central States
Kingsbury, H. N., Central States
Kingston, S. P., Central States
Kingston, T. M. S., Canada
Kinney, E. F., Central States
Kinney, J. B., Canada
Kinsel, Harry L., New England
Kipp, W. H., Pacific Northwest
Kirchoffer, W. G., Central States
Kirk, B. G., England (I. S. E.)
Kirn, Matt, Central States
Kirsner, Chas., New York
Kittrell, F. W., Federal
Kivari, A. M., California
Kivell, Wayne A., New York
Klegerman, M. H., New York
Klein, J. A., Central States
Klein, L., England (I. S. P.)
Klein, Lewis, Pennsylvania
Klein, Wm. I., New Jersey
Kleiser, Paul J., Central States
Kleven, John, Dakota
Klinck, Frank, New York
Kline, H. S., Ohio
Klingbeil, Ray J., Ohio
Knapp, Chas. A., New York
Knapp, Floyd H., New York
Knechtges, O., Central States
Knight, C. H., Canada
Knittel, E. A., Pacific Northwest
Knoedler, H. A., California
Knollman, Fred, Rocky Mountain
Knowles, Coyle E., New York
Knowlton, Dana B., New England
Knowlton, W. T., California
Knox, W. Homer, Ohio
Kochtitzky, O. W., Jr., Federal
Koebig, A. H., Jr., California
Koesterer, Edwin, Central States
Kolb, Fred W., California
Komline, T. R., New Jersey
Konichek, James T., Central States
Konwinski, S. Edward, New York
Koon, Ray E., Pacific Northwest
Koruzo, John E., Georgia
Kozma, Albert B., Pennsylvania
Kramer, Harrison W., Pacific Northwest
Kramer, Harry P., Central States
Kraus, L. S., Central States
Krause, Mark C., Pennsylvania
Krell, A. J., New York
Kremer, Robert W., Pennsylvania
Kressly, Paul E., California
Kreutter, Clarence, New York
Kroeber, Frederick V., Central States
Kronbach, Allan J., Michigan
Kroone, T. H., Ohio
Kruegel, J. L., Missouri
Krueger, A. L., Missouri
Krum, Harry J., Pennsylvania (Dual-New York)
Kuhl, F. A., Central States
Kuhner, Frank G., Central States
Kulin, Harvey J., Central States
Kunkel, Martin F., Federal
Kunsch, Walter M., Central States
Kunze, Albert T., Michigan

Laberteaux, Kenneth, Michigan
Lacy, Ilbert O., New York
Ladlow, John, Arizona
Lafferty, W. R., New Jersey
LaFrance, Fred E., Ohio
Lafreniere, Theo. J., Canada
Lakeside Engineering Corp., Associate, Att'n: R. O. Friend (Corporate), Central States
Laidlaw, C. T., Canada
Lalonde, Jean-Paul, Canada
Lamb, Chas., Canada
Lamb, Clarence F., New England
Lamb, Max R., Rocky Mountain
Lamb, Miles, Central States
Lambert, Francis J., New York
Lambert, Geo., Rocky Mountain
Lamberton, Edwin P., Ohio
Lamothe, Wilfred, New England
Lamoureux, Vincent B., Federal
Lamping, Leonard L., Pacific Northwest
Lamson, B. F., Canada
Lane, Frederick C., Canada
Lane, Graham B., Canada
Lang, Sheldon, Federal
Langdon, B. J., Federal
Langdon, L. E., Central States
Langdon, Paul E., Central States
Langelier, W. F., California
Langford, Leonard L., New York & Pennsylvania (Dual-New England)
Langlais, Zachee, Canada
Lagmuir Paints, Canada
Langshaw, C. L., England (I. S. E.)
Lannon, Wm., New England
Lanphear, Roy S., New England
Lansing, Edward S., New York (Dual-New England)
LaPlante, Raymond M., Ohio
Laraschke, Wilbert L., Ohio
Larkin, W. H., New York
Larsen, Ernest A., New York
Larsen, Stanley J., Central States
Larson, C. C., Central States
Larson, Keith D., Central States
Larson, L. L., Central States
LaRue, Luther, Ohio
Lasaga, Andres, Texas
Lassiter, L. I., North Carolina
Lauer, Wm. N., Central States
Lauramore, Horace H., Florida
Lauster, K. C., Dakota
Lautz, Harold L., Central States
LaValley, Edward C., New York
Laverty, Francis J., New York
Lawrence, H. T., Oklahoma
Lawrence, John, New York
Lawrence, Walter B., California
Lawrie, J. M., Canada
Lawson, W. R., Central States
Lawson, W. S., Canada
Lawton, Edwin, New York
Lea, J. E., England (I. S. P.)
Lea, W. S., Canada
Leach, Walter L., Ohio
Learn, Henry C., Central States
Leatherland, C. F., Canada
Leaver, Robert E., Pacific Northwest
Lebetkin, Geo., New England
LeBosquet, M., Federal
LeChard, Joseph H., New Jersey
LeClerc, Arthur B., North Carolina
Leclercq, E. P., New York
Lederer, K., California
Ledford, Geo. L., New York
Lee, Chas. H., California
Lee, David B., Florida
Lee, J. Douglas, Canada
Lee, Judson L., Pennsylvania
Lee, Ming, Central States
Lee, Oliver, Central States
Leemaster, J. F., Michigan
Leggett, F. H., England (I. S. P.)
Leggett, John T., California
Leh, Willard, Pennsylvania
Lehmann, Arthur F., New Jersey
Leigh, H. G., England (I. S. P.)
Leinbach, Harry, Pennsylvania
Leist, Ervin F., Ohio
Leland, Benn J., Central States
Leland, Raymond I., Central States
Lemay, Lionel, Canada
Lemcke, Ewald M., California
Lemieux, R. A., Canada
Lemke, Arthur A., Central States
Lemon, Paul R., California
Lendall, Harry N., New Jersey
Lenox, Jacob L., New Jersey
Lentfoehr, Chas. E., Central States
Leonard, O. M., Central States
Leonard, W. V., Rocky Mountain
Leonard, Walter E., Ohio
Leonhard, Harold M., Michigan
Lesher, C. E., Jr., Ohio
Lessig, D. H., Central States
LeVan, James H., Federal
Levan, Stephen, Central States
LeVine, Richard Y., New Jersey
Lewis, C. J., Pennsylvania
Lewis, John V., New York
Lewis, R. K., Central States
Ley, Chas. H., Canada
Ley, Herbert H., Central States
Liddle, Elmo G., Michigan
Limestone Products Corp. of America, Associate, Att'n: Peter J. Kelley
Lincoln, Robert A., New York
Lind, A. Carlton, Central States (Dual-New York)
Lindell, O. V., Central States
Linders, Edward, Federal
Lindsley R. V., England (I. S. E.)
Lindsten, H. C., Dakota
Link-Belt Co., Associate, Att'n: Wm. L. Hartley
Link-Belt Co., Att'n: Frank W. Lovett, (Corporate), Central States
Lippelt, Hans B., New York
Lium, E. L., Dakota
Livingston, L. E., Texas
Lloyd, G. H., Canada
Lobee, Frank A., Jr., New York
Locke, Edward A., New England
Lockett, W. T., England (I. S. P.)
Lockwood, Bronson E., New England
Loelkes, Geo. L., Missouri
Loftus, Harry P., New England
Logan, Robert P., New Jersey
Loiselle, Donald W., New England
Long, Chas. A., New York
Long, Frank V., California
Long, Geo., Ohio
Long, Geo. S., Pennsylvania
Longbottom, V., England (I. S. P.)
Longley, Paul N., Pennsylvania
Longwell, John S., California
Lorenz, Orval, Georgia
Lorenz, K. P., New York
Los Angeles Public Library, (California), California
Los Angeles Public Library, Serials Div., (California), California
Lose, Wm. L., New York
Losee, James R., New York
Love, S. D., Georgia
Lovejoy, W. L., Pacific Northwest
Loveless, R. W., Ohio
Lovell Clay Products Co., Att'n: R. E. Richardson, (Corporate), Montana
Lovell, Theodore R., Iowa
Lovett, F. W., Central States
Lovett, M., England (I. S. P.)
Loving, M. W., Central States
Lovrinch, Louis B., Central States
Lowden, L. J., Central States
Lowe, A. S., England (I. S. P.)
Lowe, Robert P., California
Lowe, Walter M., New York
Lozier, Wm. S., New York
Lubrotovich, M. D., Central States
Luchtenberg, R. O., Ohio
Ludlow Valve Mfg. Co., Associate, Att'n: Robert Bischoff
Ludwig, Harvey F., California (Dual-Federal)
Ludwig, Russell G., California
Ludzack, F. J., Central States
Lueck, Bernard F., Central States
Luff, R. M., Pennsylvania
Luippold, G. T., California
Lumb, C., England (I. S. P.)
Lundy, Ray E., Kansas
Luquire, Joseph W., Jr., Georgia
Luske, Wm. E., Central States
Lussier, Fabien, Canada
Lustig, Joseph, Central States
Luther, Robert W., North Carolina
Lybrook, W. M., North Carolina
Lyman, C. S., Ohio
Lynch, Daniel E., Jr., New York
Lynch, Howard J., Pennsylvania
Lynch, James T., New York
Lynchburg Foundry Co., Associate, Att'n: W. Roy Odor
Lyon, W. J., Central States
Lyons, Wm., New York

Mabbs Hydraulic Packing Co., Central States
Macabee, Lloyd C., California
Macauley, J. W., New York
MacCallum, C., New York
MacCallum, Percy C., New York
MacCrea, J. M., New York
MacDonald, J. C., Central States

MacDowell, R. F., Ohio
Mace, H. Harlan, Ohio
Mack, Frank, New York
MacKenzie, Vernon G., Federal
Mackin, J. C., Central States
MacKinnon, Ronald M., Canada
MacLaren, J. F., Canada
MacLean, J. D., Canada
MacLean, Wm. D., Canada
MacLellan, Murdock T., New England
MacNicol, N., Canada
MacVittie, Alexander, Michigan
Maga, John A., California
Maglott, Don S., Ohio
Magnuson, Francis J., Central States
Maguire, Chas. A., New England
Magwood, W. H., Canada
Maher, Mary C., Canada
Mahlie, W. S., Texas
Maier, F. J., Federal
Maier, Paul P., Federal
Main, Ralph A., Michigan
Maisel, Emanuel, Central States
Makepeace, W. H. E., England (I. S. P.)
Malcolm, Wm. L., New York
Male, L. H., Federal
Mallalieu, W. C., New Jersey
Mallmann, W. I., Michigan
Malion, Fred W., Central States
Mallory, Edward B., Pennsylvania, Central States and Michigan
Malone, J. R., North Carolina
Malony, W. L., Pacific Northwest
Malphurs, M. N., Florida
Mangones, Robert J., New York
Mann, Alfred H., New York
Mann, Karl M., New York
Mann, Uhl T., New York
Mannel, Chas., North Carolina
Mannes, C. O., Pacific Northwest
Mannheim, Robert, New England
Manning, Paul, Canada
Manock, W. R., Canada
Mansfield, Clifford S., New England
Mansfield, M. G., Pennsylvania
Manteufel, Lawrence A., Central States
Marcott, D. G., Montana
Mariner, W. S., New England
Mark, Richard S., Federal
Marquardt, Edwin G., Federal
Marr, R. B., Canada
Marshall, E. A., New York
Marshall, J. C., Michigan
Marshall, Leslie S., New York
Marshall, W. B., New York
Marshall, W. W., Canada
Marshall, Wm. D., Pennsylvania
Marston, Frank A., New England
Martens, Myron M., Central States
Martin, A. E., New York
Martin, Alexander G., New York
Martin, Arthur E., California
Martin, B. A., Georgia
Martin, Benn, California
Martin, Chas. P., California
Martin, Edward J., Jr., New York
Martin, Frank, Missouri
Martin, Geo. W., Pennsylvania
Martin, Geo. W., Central States
Martin, H. Fred, Texas
Martin, H. J., California
Martin, Phil J., Arizona
Martin, Ronald F., Canada
Martin, S. C., Central States
Marx, Frank, New York
Marx, Geo. W., Arizona
Maryland State Dept. of Health, Maryland-Delaware
Marzec, Edmund J., Iowa
Mason, E. R., Canada
Mather, Edward K., Dakota
Mather, L. A., Rocky Mountain
Mathers, Geo., New York
Matheson, Donald M., Canada
Mathews, E. R., Dakota
Mathews, Frank E., Pacific Northwest
Mathews, W. W., Central States
Mathieson Alkali Works, Inc., Associate, Att'n: J. O. Logan
Matlock, J. Ray, Oklahoma
Matter, L. D., Pennsylvania
Mattern, R. G., Ohio
Mattice, Geo., New York
Mattox, Leon, Central States
Mau, Gordon E., Iowa
Maurer, Joseph A., Pennsylvania
May, D. C., Michigan
May, Harold L., California
May, Maynard L., Florida
Mayne, Arthur H., Pacific Northwest
McAdoo & Allen Welting Co., (Corporate), Pennsylvania
McAllister, Paul J., Pennsylvania
McAnlis, Chauncey R., Central States
McArthur, Franklin, Canada
McBrien, S. R., Canada
McCabe, Joseph, New York
McCabe, Michael, Pennsylvania
McCall, R. G., Central States
McCalium, G. E., Federal
McCan, Wm. Warren, Texas
McCannel, D. A. R., Canada
McCarthy, Joseph A., New England
McCaslin, Walter R., Central States
McClain, E. C., Pacific Northwest
McClave, S. Wood, Jr., New Jersey
McClenahan, W. T., Central States
McClintock, H. C., Rocky Mountain
McClure, Ernest, Central States
McConkey, L. W., Canada
McCoombs, John A., Canada
McCoy, Lloyd R., Pennsylvania
McCrady, Mac Harvey, Canada
McCutcheon, J. R., Jr., Ohio
McDill, Bruce M., Ohio
McDonald, F. L., Arkansas
McDonald, G. S., England (I. S. E.)
McDonald, N. G., Canada
McDonnell, Geo. H., New York
McDuffie, N. J., Georgia
McFarland, Wm. H., New York
McFarlane, Walter D., Michigan
McFaul, W. L., Canada
McGeorge, W. L., California
McGrail, Paul J., Missouri
McGrath, C. P., Michigan
McGregor, Albert L., Florida
McGuire, C. D., Ohio
McGuire, J. M., Canada
McGuire, M. H., Pacific Northwest
McHugh, Basil, Pacific Northwest
McHugh, C. J., Canada
McIlvanine, Wm. D., Jr., Central States
McInerney, Gerald J., New York
McIntosh, Pierce B., California
McIntyre, F. J., Ohio
McIntyre, John C., Central States
McKay, R. Donald, Canada
McKay, W. G., Canada
McKee, Frank J., Central States
McKee, Jack E., New England
McKee, S. C., Ohio
McKeeman, Edwin C., New York
McKeen, W. H., California
McKeever, R. L., Ohio
McKenna, Harold K., Michigan
McLaren, Alfred M., California
McLaughlin, Carroll W., New York
McLaughlin, H. L., Rocky Mountain
McLaughlin, R. M., New York
McLean, D. L., Canada
McLean, R. F., Pacific Northwest
McLoughlin, Chas. A., Federal
McMahon, Walter A., New England
McManamna, T. L., Canada
McMath, Eben G., Central States
McMenamin, C. B., New Jersey
McMillan, Donald C., California
McMillen, C. L., Pennsylvania
McMorrow, B. J., California
McMorrow, Thomas M., California
McMullen, Wm., Central States
McNamara, W. P., Pacific Northwest
McNamee, Paul D., Federal
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McNiven, R., Canada
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McWilliams, D. B., Canada
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Mechanik, Joseph, New York
Medberry, H. Christopher, California
Medland, C. R., Canada
Meeker, Herbert J., New York
Megregian, Stephen, Federal
Mendelsohn, Isador W., Maryland-Delaware
Menzies, J. Ross, Canada
Mercer, H. S., England (I. S. P.)
Merkel, Paul P., Pennsylvania
Merlo, Louis A., Jr., Canada
Merrick, Ray, Central States
Merrill, Joseph, Canada
Merrill, Walter E., New England
Merryfield, Fred, Pacific Northwest
Merwin, Joseph K., New England
Merz, H. Spencer, Central States
Merz, R. C., Central States (Dual-Michigan)
Metcalf, H. B., Central States
Metzger, Jesse, Central States
Meyer, Carle, New England
Meyer, Louis P. H., California
Michael, Fred C., New York
Mick, K. L., Central States
Mickel, John C., Central States
Mickle, Chas. T., Central States
Middleton, Francis M., Federal
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Miick, Fred E., California
Miles, Henry J., California
Milham, Alfred J., Missouri
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Miller, A. S., England (I. S. P.)
Miller, Alden W., Arizona
Miller, Arthur P., Federal
Miller, David R., Central States
Miller, Fred M., New York
Miller, J. John, Pennsylvania
Miller, John B., Florida
Miller, John E., Michigan
Miller, L. A., Central States
Miller, L. E., Iowa
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Miller, Maurice L., Central States
Miller, Noble, Central States
Miller, Norman A., Michigan
Miller, Olly G., Canada
Miller, Robert H., Pennsylvania
Miller, W. C., Canada
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Milling, Martin A., Central States
Mills, W. Stuart, Canada
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Moehr, Louis H., Michigan
Moeller, Carl, Central States
Moeller, Wm. H., New York
Mogelnicki, Stanley J., Michigan
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Molitor, Paul, Jr., New Jersey
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Montagna, S. D., Pennsylvania
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Moore, Edward W., New England
Moore, Emmett B., Pacific Northwest
Moore, F. Owen, England (I. S. E.)
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Moore, Geo. W., New York
Moore, H. Carlton, New England
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Moore, R. B., Central States
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Morris, Grover L., Oklahoma
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Morrisey, Richard A., Pennsylvania
Morrison, Geo. A., Pennsylvania
Morrison, James E., Pacific Northwest
Morrison, John H., Montana
Morrow, Ben S., Pacific Northwest
Morrow, T. L., Oklahoma
Mortensen, Ernest D., New England
Mortenson, E. N., Central States
Moses, H. E., (Honorary) Pennsylvania
Moss, F. J., Federal
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Moulton, David E., New England
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Moyer, Jesse, Ohio
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Munroe, Walter C., Maryland-Delaware
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Murdock, Chas. R., Canada
Murdock, Wm. J., Pennsylvania
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Murphy, Reginald A., New York
Murray, A. E., Scott, England (I. S. E.)
Murray, K. A., England (I. S. P.)
Murschel, Jacob, Dakota
Musgrave, A. S. G., Canada
Mutzberg, F. A., North Carolina
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Myers, R. N., Pennsylvania
Myles, Geo., Michigan

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Nangle, B. A., Dakota
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Nelle, Richard S., Central States
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Nelson, D. H., Central States
Nelson, Frederick G., California
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Neuffer, Geo. T., Ohio
Neumann, Geo. B., Central States
Neves, Lourenco Baeta, New York
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Newell, M. A., Rocky Mountain
Newell, Town of, Iowa
Newland, Stewart H., Texas
Newlands, James A., New England
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Newton, City of, Iowa
Newton, Donald, Central States
Nicholas, Forrest A., Central States
Nichols, Arthur E., New York
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Nichols, R. L., Maryland-Delaware
Nicholson, C. P., New York
Nickle, A. J., Canada
Nicklin, H. S., Canada
Nicklis, Jim, Ohio
Niebergall, Herbert J., New York
Nielsen, N. P., Rocky Mountain
Nieman, Hubert W., Central States
Niles, A. H., Ohio
Niles, Chas. A., New York
Niles, Thomas M., Central States
Nilmeier, Herbert P., California
Nix, Ed, Oklahoma
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Nixon, Ray, Kansas
Noel, Carl F., California
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Nollett, Frank, New York
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Nordell, Carl H., Central States
Norfleet, Clark T., California
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Norris, Francis I., Federal
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Nottingham, M. C., California
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Nussbaumer, Newell L., New York
Nussberger, Fred, New York
Nutter, Frank H., Central States

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O'Brien, Earl F., New York
O'Brien, Frank, Oklahoma
O'Brien, Jas. E., New York
Ocean City Sewer Service Co., New Jersey
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O'Connor, Wm. F., Jr., New York
Odbert, Eugene, Jr., Central States
Odell, Lester, Central States
O'Dell, W. H., New York
O'Donnell, Chas. F., New York
O'Donnell, R., Pennsylvania
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Oeming, Loring F., Michigan
O'Flaherty, Fred, Ohio
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Ogden, Willis L., Federal
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O'Hara, John, Pennsylvania
Ohr, Milo F., Michigan
Oke, Ernest E. W., Canada
Okun, Abraham H., New York
Okun, Daniel A., Central States
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O'Leary, W. A., New York
Olewiler, Grant M., Pennsylvania
Olin, Ralph H., Michigan
Oliver, Warren J., Rocky Mountain
Olney, H. Ross, California
Olsen, W. C., North Carolina
Olson, Frank W., Central States
Olson, Herbert A., New England
Olson, Jack, Rocky Mountain
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Onions, Robert, Canada
Ontario Construction Co., Canada
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Orford, Harold E., New Jersey
Orr, Wm. S., Canada
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Osenbaugh, R. J., Rocky Mountain
Oskaloosa, City of, Iowa
Osorio, Luis Angel, Florida
Osterhoudt, Wm. C., New York
Osthoff, Richard H. L., Jr., New Jersey
Otts, Louis E., Jr., Texas
Ousterhout, Alfred, New York
Overall, W. G., Central States
Owen, Mark B., Canada and Central States
Owers, Leonard E. A., Canada
Ozelsel, A. M., Central States

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Pallo, Peter E., New York
Palmer, Benjamin M., New England
Palmer, C. L., Michigan
Palmer, F. F., Montana
Palmer, Harold K., California
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Palocsay, Frank S., Ohio
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Pardew, W. Holmes, Pennsylvania
Parker, H. C., California
Parker, Ivy, Georgia
Parker, L. K., New England
Parker, R. S., Missouri
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Parks, C. A., Pacific Northwest
Parks, Walter J., Jr., Florida
Parrish, Miles A., California
Parrish, Rial T., Ohio
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Parsons, R. H., Canada
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Patrick, E. E., Montana
Patterson, J. R., Missouri
Patterson, Orville W., Central States
Patterson, Roy K., New York
Paul, Lewis C., New York
Paulette, Robert G., New York
Pawlak, John S., New York
Payrow, Harry G., Pennsylvania
Payton, Louis S., Missouri
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Peake, J. B., New York
Pealer, Thomas, Pennsylvania
Pearce, Fletcher W., Montana
Pearce, H. B., Arizona
Pearl, Emanuel H., Texas
Pearse, Langdon, (Honorary) Central States
Pease, Maxfield, Ohio
Peck, Lawrence J., New York
Pederson, Jean J., California
Pedigree, Richard B., New England
Peirson, Nat D., North Carolina
Pelon, Guy, New York
Pelty, Wm., Ohio
Pence, Irel V., Central States
Pennington, Marvin, Central States
Pennsylvania Salt Mfg. Co., Associate, Att'n: B. P. Steele
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Pepperman, Cecil M., Pennsylvania
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Perkins, C. K., New York
Perkins, Harold, New York
Perrine, J. Franklin, New York
Perry, A. H., Canada
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Pessina, John, Michigan
Peters, Stanley, Canada
Peterson, Earl L., New York
Peterson, Edward T., Central States
Peterson, F. E., Central States
Peterson, Ivan C., Central States
Peterson, J. H., California
Peterson, Myhren C., Central States
Peterson, Ralph W., Central States
Petrie, Wm. P., New England
Pett, K. M., Central States
Pettit, Chas. G., Ohio
Pfenning, C. M., New England
Phelps, B. D., California

Phelps, Boyd E., Central States
Phelps, Earle B., New York
Phelps, Ellis K., Florida
Phelps, Geo., Canada
Philips, H. S., Canada
Phillips, C. J., Pacific Northwest
Phillips, H. N., New York
Phillips, M. H., Arkansas
Phillips, Max, Ohio
Phillips, Robert S., North Carolina
Phillips, Roy L., Pennsylvania
Phillips, W., England (I. S. P.)
Phoenix, Edward A., New York
Piatt, Wm. M., North Carolina
Pickett, Arthur G., California
Picton, Walter L., Federal
Pieczonka, Thaddeus, New York
Pierce, C. L., California
Pierce, D. O., California
Pierce, Donald M., Michigan
Pierce, Geo. O., Central States
Pierce, H. M., Dakota
Pierron, L. L., Ohio
Pimm, Alan B., Florida
Pincus, Sol, New York
Pine, E. T., Central States
Pinkney, Glenn E., New York
Pinney, F. W., Dakota
Piper, K., Dakota
Pitkin, Ward H., New York
Pittsburgh-Des Moines Co., Associate, Att'n: J. E. O'Leary
Pittsburgh Equitable Meter Co., Associate, Att'n: W. F. Weimer
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Pledger, A., England (I. S. P.)
Plum, Svend, Michigan
Plummer, M. W., Montana
Plummer, Raymond B., Central States
Pohl, C. A., New York
Pope, Lester, New Jersey
Pollard, R. T., Oklahoma
Pollex, Elmer, Ohio
Pollock, John M., New York
Pomeroy, Richard, California
Poole, B. A., Central States
Poole, S. B., England (I. S. P.)
Poole, Wm. A., California
Porges, Ralph, Federal
Porteous, W. K., England (I. S. E.)
Porter, H., California
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Porter, Sam D., Michigan
Porter, Thomas H., Canada
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Poston, R. F., Federal
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Potter, H. M., Maryland-Delaware
Potts, Clyde, New York
Potts, Harry G., Michigan
Powell, A. R., New York
Powell, G. G., Canada
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Powell, Reuben R., Florida
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Rath, Henry M., New York
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Regan, Chas. L., New York
Regester, Robert T., Maryland-Delaware
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Rehler, Joseph E., New York
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Richter, Paul O., Central States
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Riddick, Thomas M., New York
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Riedesel, G. A., Pacific Northwest
Riedesel, Henry A., Central States
Riedesel, P. W., Central States
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Roberts, E. F., Canada
Roberts, F. C., Jr., Federal
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Roberts, W. C., California
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Rogers, D. Paul, Pennsylvania
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Rogers, M. W., Canada
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Rostenback, Royal E., Federal
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Rumble, G. B., Canada
Rummel, Edward F., Maryland-Delaware
Rumsey, James R., Michigan
Ruppert, E. L., Pacific Northwest
Ruscica, Samuel, Canada
Russell, Donald F., Pennsylvania
Russell, George S., Missouri

Russell, J. P., Canada
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Ryan, J. Samuel, New York
Ryan, Wm. A., New York
Rybolt, Howard R., Florida
Rymer, Mary E., Rocky Mountain

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Sampson, Geo. A., New England
Samson, Channel, New York
Samson, R. A., Rocky Mountain
Sanborn, J. F., New York
Sanchis, Joseph M., California
Sander, Irwin P., New York
Sanderson, W. W., New England (Dual-New York)
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Saville, Thorndike, New York
Sawyer, Clair N., New England
Sawyer, Robert W., Jr., New England
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Schade, W. F., Ohio
Schaefer, Edward J., New York
Schaetzle, T. C., Ohio
Schatz, Robert J., Pennsylvania
Schaut, Geo. G., Pennsylvania
Scheak, H. M., Canada
Scheffer, Louis K., Pennsylvania
Scheid, Chas. R., California
Scheidt, Burton A., Central States
Schenk, E. F., Iowa
Scherf, Albert W., Central States
Schick, V. R., Ohio
Schier, Lester C., Central States
Schirk, J. M., Rocky Mountain
Schlechty, Eugene W., Ohio
Schliekelman, R. J., Iowa
Schlenz, Harry E., Central States
Schloss, Chas. M., Rocky Mountain
Schlueter, Wm. H., Central States
Schmidt, John W., Ohio
Schmit, J. M., Montana
Schneider, Warren A., California
Schoen, Daniel, New York
Schoepfle, O. F., Ohio
Schott, Edgar A., California
Schouten, Ernest W., Oklahoma
Schrader, Elmer C., Montana
Schran, Ray, Oklahoma
Schreiner, W. R., New York
Schriner, P. J., Central States
Schroeder, Arthur W., Central States
Schroeder, G. W., Canada
Schroepfer, Geo. J., Central States
Schuck, H. W., California
Schulhoff, Henry B., New York
Schultz, Ray W., Central States
Schureman, A. L., California
Schwartz, Chas. F., New York
Schwartz, H. L., Pennsylvania
Schwartz, Louis, New York
Schweiterman, Ernest T., Ohio
Schwob, Carl E., Federal
Sciver, A., England (I. S. E.)
Scott, Cliffton A., Central States
Scott, G. R., Federal
Scott, H. E., Oklahoma
Scott, J. Russell, Canada
Scott, Ralph, Central States
Scott, Roger J., Central States
Scott, Rossiter S., New York
Scott, W., England (I. S. P.)
Scott, W. M., Canada
Scott, W. R., Georgia
Scott, Walter M., New York
Scott, Warren J., New England
Scovill, John R., New York
Scudder, A. P., New York
Seabrook, C. S., Pacific Northwest
Searls, Glenn, New York
Searight, Geo. P., Pennsylvania
Seaver, Wirt D., Missouri
Seeger, W. R., California
Segel, A., California
Seibert, Frank W., Ohio
Seid, Sol., New Jersey
Seidel, Harris F., Central States
Seidel, R. David, Ohio
Seifert, Wm. P., New York
Seitel, G. C., California
Seiver, Clark H., Oklahoma
Sellinger, Frank, Ohio
Seltzer, J. M., Pennsylvania
Sencey, Joe, Central States
Senseman, Wm. B., California
Seram, A. J., Oklahoma
Setter, Lloyd R., New York
Sewage Works Engineering, Associate, Att'n: Karl M. Mann
Shank, John J., Pennsylvania
Shannon, R. C., Michigan
Shapiro, Robert, New York
Shapley, Wm. H., Iowa
Shard, R. H., England (I. S. P.)
Sharp, G. W., Canada
Sharp, Perry C., Federal
Sharp, R. K., Canada
Shaw, Arthur L., New England
Shaw, Frank R., Federal
Shaw, Morton, Central States
Shaw, Paul A., California
Shea, Walter J., New England
Sheaffer, G. Edgar, Pennsylvania
Shearer, A. B., California
Sheen, Robert T., Pennsylvania
Sheets, W. D., Ohio
Shenk, Raymond U., Pennsylvania
Shephard, W. F., Michigan
Shepperd, Frederick, New York (Dual-New England)
Shera, Brian L., Pacific Northwest
Sherard, Ray L., Rocky Mountain
Sherman, Leslie K., New England
Sherratt, Gayle F., Pennsylvania
Shertzer, J. H., Pennsylvania
Sherwood, Nial, New York
Sherwood, Patricia, Florida
Sherwood, Wm. H., Arizona
Shields, James L., Pennsylvania
Shiffer, Russell R., Pennsylvania
Shikles & Co., J. W., Missouri
Shilling, LaVern G., California
Shillinger, Wm. D., Central States
Shivers, Clifford H., Pennsylvania
Shockley, C. A., Missouri
Shockley, Homer G., New York
Shoebotham, T. B., Central States
Shook, H. E., California
Shook, Howard R., Canada
Showalter, Chas. M., Pennsylvania
Shupe, S., Canada
Sickler, Archie H., New York
Sidle, R. S., England (I. S. P.)
Sieber, John D., Pennsylvania
Siebert, C. L., Jr., Pennsylvania
Siebert, Christian L., Pennsylvania
Siegel, John A., California
Signor, C. V., Pacific Northwest
Sigworth, E. A., New York
Silberbauer, Walter R., California
Simmerman, John H., New Jersey
Simmonds, I. G., Canada
Simon, Samuel S., New York
Simon, Sheldon A., Pennsylvania
Simone, Peter, Canada
Simonton, Lewis R., Georgia
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Simpson, Rolland W., New York (Dual-Pennsylvania)
Simpson, Wm. P., Pennsylvania
Singer, Oscar C., Ohio
Singleton, M. T., Georgia
Sisler, H. H., Pacific Northwest
Sitler, W. S., Pennsylvania
Siverts, Samuel A., California
Sivyer, Wm., Pennsylvania
Skinner, J. F., California (Dual-New York)
Sklarevsky, Rimma, Maryland-Delaware
Slagle, Elmer C., Central States
Slankard, M. W., California
Sleath, Aubrey B., New England
Slee, Angus E., Rocky Mountain
Sleeger, Warren H., Central States
Sloan, Garrett, Maryland-Delaware
Slocum, Adelbert I., New York
Slough, John, New York
Small, Harry, New York
Smallwood, Chas. J., Michigan
Smith, A. H., Ohio
Smith, Benjamin L., New York
Smith, Bernard F., Pennsylvania
Smith, C. A., California
Smith, Campbell T., Canada
Smith, David B., Florida
Smith, Doyle, Oklahoma
Smith, E. A. Cappelen, New York
Smith, E. E., Canada
Smith, E. E., Ohio
Smith, Earl T., Michigan
Smith, Edward J., New York
Smith, F. L., Canada
Smith, Frank J., New York
Smith, G. C., England (I. S. P.)
Smith, H. G., California
Smith, Harold, New York
Smith, Harold L., Michigan
Smith, J. F., California
Smith, J. Irwin, Central States
Smith, John, Canada
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Smith, Meloy, New York
Smith, Morris B., New Jersey
Smith, Paul L., Maryland-Delaware
Smith, R. C., New Jersey
Smith, R. L., Central States
Smith, R. Trumbull, Pacific Northwest
Smith, Ralph A., Central States
Smith, Robert J., Michigan
Smith, Russell S., Federal
Smith, S. H., Michigan
Smith, W. A., England (I. S. P.)
Smith, W. T. E., Canada
Smith, Walter E., Michigan
Smith, Willard R., New York
Smithson, Thomas, Pacific Northwest
Smithwick, S. Carl, Pacific Northwest
Sneath, Roy G., Canada
Snedeker, L. LeVern, Michigan
Snell, J. R., New England
Snelsire, Wm., Pennsylvania
Snider, L. N., Central States
Snook, W. F. A., England (I. S. P.)
Snow, Donald L., Central States (Dual-Federal)
Snow, Ernest A., Jr., New England
Snow, Willis J., New England
Snyder, John A., Jr., California
Snyder, M. K., Pacific Northwest
Snyder, N. S., New York
Snyder, R. F., Ohio
Solander, Arvo A., Federal
Solvay Sales Corp., Att'n: Norman C. Weil, (Corporate), New York
Somers, Verne, Central States
Sommerfeldt, Everett L., New York
Sorrels, Joe H., Texas
Soule, Ralph M., New England
Sourbeer, Francis M., Pennsylvania
Southard, Harold, New York
Sowdon, Wm. K., New York
Spaeder, Harold J., Central States and Ohio
Spaeth, Julius, Kansas
Spahr, H. E., Ohio
Sparks, Geo. H., Georgia
Sparks, Wm. A., New York
Sparling, R. W., Arizona
Sparr, A. E., New York
Spaulding, L. H., Pacific Northwest
Spear, James J., California
Spear, Wm. B., Pennsylvania
Specht, J. E., Ohio
Speiden, H. W., Pennsylvania
Speirs, Geo. W., New York
Spencer, A. W., Michigan
Spencer, Albert W., New York
Spencer, C. C., Federal
Spencer, City of, (Iowa), Iowa
Sperling, Elmer J., Florida

Sperry, John R., Central States (Dual-Ohio)
Sperry, Walter A., Central States
Spicer, C. H., Michigan
Spiegel, Milton, Central States
Spieker, Roy G., Dakota
Spielvogel, Chester R., New England
Spier, Daniel R., New York
Spies, Kenneth H., Pacific Northwest
Sporseen, Stanley E., Pacific Northwest
Spotts, Walter E., Pennsylvania
Spragg, H. J., Iowa
Sprague, Geo. M., Rocky Mountain
Spriggs, W. R., England (I. S. P.)
Spry, Fred J., New York
Spurgeon, Ralph, Central States
Staby, Walter R., Arizona
Stache, Paul, New York
Stack, John P., Central States
Stalbird, James A., New York
Staley, H. H., Kansas
Stalker, W. D., Canada
Stanbridge, H. H., England (I. S. P.)
Stanhope, Clifford T., New York (Dual-Pennsylvania)
Stanley, C. M., Iowa
Stanley, Don R., Canada
Stanley, Joe A., Texas
Stanley, Wm. E., New England
Stapf, R. J., Dakota
Stapley, Edward R., Oklahoma
Stark, Louis, Michigan
Starks, Lee W., Rocky Mountain
Starnes, Tom M., Georgia
Stauff, Paul V., Central States
Staven, Julian, Dakota
Staynes, E. H., England (I. S. P.)
Stearns, Donald E., New York
Stebel, H. M., Ohio
Steck, Robert F., Pennsylvania
Steeg, Henry B., Central States
Steele, Frank C., Ohio
Steffen, Alfred J., Central States
Steffensen, S. W., New York
Steffes, Arnold M., Central States
Stegeman, Paul, Michigan
Steindorf, R. T., Central States
Steiner, Joseph, Central States
Steiner, S. K., New York
Steinman, R. W., Oklahoma
Stepanek, Chas. H. B., New York
Stepleton, Harold A., Ohio
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Sterns, Edward A., New York
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Stevenson, Albert H., NewYork(Dual-Federal)
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Stewart, Dueray L., California
Stewart, Earl, Canada
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Stewart, F. D., Ohio
Stewart, H. M., Pennsylvania
Stewart, Jesse A., California
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Stewart, M. D., Canada
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Stilson, Alden, Ohio
Stinson, Robert, Pennsylvania
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Stockfish, H. G., Canada
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Stockman, R. C., California
Stockman, R. L., Pacific Northwest
Stoker, E. C., England (I. S. P.)
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Stone, A. R., England (I. S. P.)
Stone, Ralph, Florida
Stone, W. Allen, Federal
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Storrie, Wm., Canada
Stotkoe, O. H., Missouri
Stotter, Meyer, New Jersey
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Strand, Philip E., Central States
Strandburg, Chas. J., New York
Strang, J. A., Kansas
Stratton, Chas. H., New York
Straub, Conrad P., New York (Dual Federal)
Street, Haskell R., Texas
Street, John Z., Pennsylvania
Streeter, Eldon R., Central States
Streeter, H. W., Federal
Streeter, Robert L., Rocky Mountain
Streeter, S. H., England (I. S. E.)
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Striger, R. M., Georgia
Strine, S. M., Ohio
Strockbine, Walter, Pennsylvania
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Sulesky, Adam E., New England
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Susser, Paul L., Ohio
Sutcliffe, H. W., Canada
Suter, Max, Central States
Sutter, Oliver, Ohio
Suttie, R. H., New England
Sutton, R. W., England (I. S. P.)
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Swab, Bernal H., North Carolina and Pennsylvania
Swarthout, T. L., Ohio
Swartz, Martin, North Carolina
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Swenholt, John, New York
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Swope, H. Gladys, Central States (Dual-Pennsylvania)
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Sylvester, R. O., Pacific Northwest
Sylvester, Wm. L., New York
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Symons, Kelvin E. B., Canada
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Szymanski, Walter C., California

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Tallent, Lee H., Rocky Mountain
Talley, Dean, Montana
Tamer, Paul, New York
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Tapping, C. H., Central States
Tarbell, W. Park, Dakota
Tarbett, R. E., Federal
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Tarlton, Ellis A., New England
Tarman, John E., Pennsylvania
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Taylor, F. W., Georgia
Taylor, Frank S., Oklahoma
Taylor, Godfrey M. C., England (I. S. E.)
Taylor, H., England (I. S. P.)
Taylor, Henry W., New York (Dual-New England and Pennsylvania)
Taylor, J., England (I. S. P.)
Taylor, J. C. D., Canada
Taylor, Jack, Pacific Northwest
Taylor, Warren G., New York
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Teisinger, Fred, Iowa
Tempest, W. F., Central States
Tennant, H. V., Central States
Terhoeven, G. E., Federal
Ternent, Andrew, Canada
Terrill, James G., Jr., California (Dual-Federal)
Terry, Frank, New York
Tetzlaff, Frank, New York (Dual-Federal)
Thalheimer, Marce, Central States
Thamasett, Otto E., New York
Thatcher, E. F., Missouri
Thatcher, Fred A., New York
Thatcher, H.D., England (I. S. P.)
Thatcher, Lynn M., California
Thayer, Neal B., Arkansas
Thayer, Paul M., Central States
Thayer, Reginald H., New York
Theriault, E. J., Federal
Thews, Vernon W., California
Thoits, E.D., California
Tholin, A.L., Central States
Thoman, John R., Federal
Thomas, A., England (I. S. P.)
Thomas, A. H. R., Canada
Thomas, Ariel A., New England
Thomas, E. C., Canada
Thomas, E. R., North Carolina
Thomas, Vernon B., Ohio
Thompson, Bernard, Dakota
Thompson, Glen O., Central States
Thompson, H. Loren, Pacific Northwest
Thompson, N. J., Rocky Mountain
Thompson, Robert B., New England
Thompson, S. E., Central States
Thompson, Thomas C., New York
Thompson, Walter E., New England
Thomson, J. B. F., New York
Thon, A. H., Central States
Thorn, Wm. J., Pennsylvania
Tierney, Lawrence J., Jr., New England
Tierney, Lawrence J. J., New England
Tigrak, Mehmet Fuat, Central States
Tims, Wm. Calvin, Florida
Tingley, Clement, Pennsylvania
Tinnie, Donald, New York
Tippy, Kenneth Clem, New England
Todd, J. L., California
Todd, Lee O., Texas
Todd, Leon J., Central States
Todd, Stanley B., New York
Tolles, Frank C., Ohio
Tolman, S. L., New York
Tomek, Arthur O., Central States
Tomm, LaVern M., New York
Tompkins, Lloyd, Michigan
Torpey, Wilbur N., New York
Tovey, C. A., Florida
Towne, John W., Central States
Towne, W. W., Dakota
Townend, C. B., England (I. S. P.)
Townsend, Darwin W., Central States
Tracy, Edward L., New England
Trager, Leonard W., New England
Trautman, Robert J., Maryland-Delaware
Travaini, Dario, Arizona
Travers, V. P., Florida
Trebler, H. A., Pennsylvania
Treem, Geo. O., California
Treo, Alfons, Pennsylvania
Troemper, A. Paul, Central States
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Trotter, Roy M., California
Trulander, Wm. M., Central States
Tuhus, Kenneth O., Central States
Turland, C. N., Canada
Turley, Comer, Georgia
Turner, J. R., Ohio
Turner, N. P., Texas
Turner, Wm. S., Pacific Northwest
Turpin, U. F., Central States
Tuttle, Leon E., New England
Tykosky, Frank, Michigan
Tyler, H. G., Canada
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Tyler, Jacob W., New York
Tylicki, Frank D., Ohio

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Van Atta, J. W., New York (Dual-New England and Pennsylvania)
Van Breda, A. J., Central States
Vandenberg, Alfred John, California
Van Denburg, J. W., New York
Vanderlip, Arthur N., New York
Van Der Vliet, Henry, New Jersey
VanDerwerker, Ralph J., Federal
Van Deusen, E. J., New York
Van Deventer, M. S., Missouri
Vandiver, Wm. A., Ohio
Van Horn, R. B., Pacific Northwest
Van Kleeck, LeRoy W., New England
Van Ness, Joseph A., Rocky Mountain
Van Norman, Jas. H., California
Van Pelt, Richard, California
Van Praag, Alex, Jr., Central States
Vapor Recovery Systems Co., Associate, Att'n: C. T. Stanhope
Vaseen, V. A., Rocky Mountain
Vaughan, E. A., California
Veale, J. C., England (I. S. P.)
Veatch, F. M., Rocky Mountain
Veitch, Wm. M., Canada
Velz, C. J., New York
Velzy, Chas. R., New York
Venables, W. N., Canada
Venn, Frank, Michigan
Vensano, H. C., California
Venton, Donald M., Canada
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Verhoek, J. B., Central States
Verlinden, Albert, New York
Vermette, F. L., Michigan
Vest, W. E., North Carolina
Victoria, John, New York
Vincent, G. G., Canada
Vinson, A. T., Florida
Vivier, Harvey, New England
Voden, Stewart, Montana
Vogelbein, Chas. J., Missouri
Vognild, R. O., Pacific Northwest
Voigt, Richard C., New York
Volonte, August F., Maryland-Delaware (Dual-Federal)
Volpp, A. G., Pacific Northwest
Vosicky, Frank E., Pennsylvania
Vredenburg, Edward L., New York
Vrooman, Morrell, New York

Waddell, W. H., Canada
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Wadhams, S. H., New England
Wagenhals, H. H., New York
Waggoner, E. R., California
Wagner, E. P., New York
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Wagner, Norman W., New England
Wahlstrom, Carl A., Central States
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Waite, Paul W., Pennsylvania
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Walbridge, Thornton, Central States
Waldor, N. T., Central States
Walker, C. C., Ohio
Walker, Chas. L., New York
Walker, Edward A., Pennsylvania
Walker, Emerson, Pennsylvania
Walker, J. Donald, Central States
Walker, James G., New York
Walker, W. P., Jr., Texas
Walker, Wm. W., Federal
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Ward, A. R., England (I. S. P.)
Ward, C. N., Central States
Ward, Chas. E., New York
Ward, Oscar, Central States
Warden, Lotus A., Central States
Wardle, J. McClure, New York
Wardwell, T. M., Central States
Ware, Howard, New York
Waring, F. H., Ohio
Warner, E. L., Pacific Northwest
Warren, E. G., New Jersey and Pennsylvania
Warren, Geo. D., New York
Warrick, L. F., Central States
Washburn, Howard C., New York
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Water and Sewage Works, Associate
Waterman, Earle L., Iowa
Waters, Geo. E., Central States
Watkins, S. C., Pacific Northwest
Watmough, W. W., Canada
Watson, C. K. F., England (I. S. P.)
Watson, Carl H., New York
Watson, David M., England (I. S. E.)
Watson, H., England (I. S. P.)
Watson, Henry G., Rocky Mountain
Watson, W., England (I. S. P.)
Watters, T. C., Central States
Watts, M. R., Pennsylvania
Weachter, Horace, Pennsylvania
Weasner, Leo, Central States
Weaver, E. D., Canada
Webber, R. H., Canada
Weber, Robert R., Ohio
Webster City, City of, (Iowa), Iowa
Webster, Roy W., Pacific Northwest
Wechter, W. H., New York
Weckel, W. O., California
Wedeman, John D., New York
Weed, Sam A., California
Weibel, S. R., Federal
Weil, Harold M., New York
Weir, E. McG., England (I. S. P.)
Weir, W. H., Georgia
Weisel, W. O., Pennsylvania
Weiss, R. H., Texas
Welch, Dewey, Missouri
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Wells, E. Roy, Central States
Welsch, W. Fred, New York
Wenger, J. H., Ohio
Wentworth, John P., New England
Wertz, C. F., Pennsylvania
Wertz, Leroy F., Ohio
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West, A. W., Central States
West, Ezra, California
West, L. E., New Jersey
Westegaard, Viggo, New York
Westfall, Milton, Central States
Westgate, Thomas A., California
Weston, Arthur D., New England
Weston, H. S., England (I. S. P.)
Weston, Roy F., Pennsylvania
Westwood, H. W., England (I. S. E.)
Wheeler, C. E., Jr., Central States
Wheeler, Robert C., New York
Wheelock, Richard, New England
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Whipple, Melville C., New England
Whisler, B. A., Iowa and Pennsylvania
Whitby, Stephen S., Pennsylvania
White, F. L., Pennsylvania
White, Geo. C., California
White, H. H., California
White, Paul R., Central States
White, R. E., California
White, R. H., England (I. S. E.)
White, Roy, Central States
White, W. W., California
Whitehead, F. E., New Jersey
Whitlock, Ernest W., New York
Whitlock, Henry C., New England
Whitney, Alfred C., Central States
Whitney, J. S., Florida
Whittaker, J. A., Central States
Whittle, J., England (I. S. P.)
Wiedenhoefer, E. P., Michigan
Wiest, Gordon H., Pennsylvania
Wieters, A. H., Iowa
Wigley, Chester G., New York
Wild, Harry E., Florida
Wiley, Averill J., Central States
Wiley, John S., Federal
Wilkes, F. Dean, Canada
Will, Edgar G., Ohio
Willett, C. K., Central States
Williams, A. C., Pennsylvania
Williams, Chas. H., Pacific Northwest
Williams, Chas. W., Central States
Williams, Clyde E., Central States
Williams, Fred, Canada
Williams, Geo. W., Central States
Williams, J. E., Texas
Williams, J. T., Canada
Williams, L. O., Jr., Rocky Mountain
Williams, Leon G., Central States
Williams, R. O., New Jersey
Williams, W. B., Michigan
Williams, Wm. D., Pennsylvania
Williamson, A. E., Jr., Florida
Williamson, Dewey, Missouri
Williamson, Joe, Jr., Florida
Wilson, Alex, Canada
Wilson, C. T., Iowa
Wilson, E. M., Pennsylvania
Wilson, F. E., Florida
Wilson, Harry L., Central States
Wilson, John N., Federal
Wilson, J. Preston, Rocky Mountain
Wilson, Kenneth I., New England
Wilson, Murray A., Kansas
Wilson, N. Bruce, Canada
Wilson, R. D., Central States
Wilson, Robert A., Central States
Wilson, Ross E., Canada
Wilson, W. G., Canada
Wilson, Walter, Texas
Wilson, Wm. B., Canada
Wilson, Twiford C., California
Wilt, M. E., Pennsylvania
Winch, Norman M., New England
Windridge, M. E. D., England (I. S. P.)
Winebrenner, K. J., Montana
Winfield, Wilmer M., New York
Wing, Frederick K., New York
Winne, Geo., New York
Winsch, Chas. E., Pennsylvania
Winsor, C. E., England (I. S. P.)
Winston, Joe B., Texas
Winterer, R. C., Central States
Wintersgill, A. T., California
Wirt, R. M., Pennsylvania
Wirts, John J., Ohio
Wise, Melvin J., California
Wise, Wm. S., New England
Wisely, F. E., Central States
Wisely, W. H., Central States
Wismer, J. Earl, Pennsylvania
Wisniewski, T. F., Central States
Witcher, C. Preston, Michigan
Wittenmyer, James D., Ohio
Wittmer, Earl F., Ohio
Wittwer, N. C., New Jersey
Woese, Carl F., New York
Wolfs, John R., Ohio
Wolfteich, John, New York
Wolman, Abel, Maryland-Delaware
Wolterink, Paul, Michigan
Woltmann, J. J., Central States
Woo, Francis H., California
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Wood, Ernest A., Canada
Wood, Fred H., Canada
Wood, Geo. L., California
Wood, Herbert M., New York
Wood, J. R., Canada
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Woodruff, F. L., Ohio
Woods, W. G., Canada
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Woodward, Richard L., Federal
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Woolidge, H. V., Canada
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Worman, Geo. M., New England
Wormuth, W. H., New York
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Worthington, Erastus, New England
Worthington Pump & Machinery Co., Associate

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Wright, Chas. T., Federal
Wright, Chilton A., New York
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Wright, Edward C., Missouri
Wright, L. R., California
Wright, Scott, Texas
Wurtenberger, Helen, Central States
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Wyckoff, H. A., Georgia
Wyllie, Geo. F., Michigan
Wymore, Allan H., Missouri

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Yerkes, Milton R., Pennsylvania
Yoder, M. Carleton, California
Yost, Harold W., Arizona
Young, Alden W., New York
Young, C. H., Pennsylvania
Young, F. H., Ohio
Young, John T., California
Young, Norman C., Pennsylvania
Young, Wendell E., Texas
Yow, W. E., North Carolina

Zack, Samuel I., Pennsylvania
Zander, Karl L., Federal
Zele, Alexander S., New York
Zeller, P. J. A., Texas
Ziegler, C. H., Pennsylvania
Zievers, Robert J., California
Zimmer, Frank J., Missouri
Zimmer, W. E., Michigan
Zoglmann, Martin, Central States
Zorn, Ray H., Ohio
Zydallas, Chas., New Jersey